THE OHIO JOURNAL OF SCIENCE

VOL. XLVI SEPTEMBER, 1946 No. 5

THE GEOLOGIC INTERPRETATION OF SCENIC FEATURES IN OHIO[1]

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INTRODUCTION

To the geologist there are no everlasting hills. The relief features of the earth's surface as we find them today are the result of the work of geologic agents, such as running water, wind, glacial ice; working by geologic processes such as weathering, erosion, transportation, deposition; on geologic materials, the rocks; through long intervals of geologic time. An even sky-line in a rugged region, a level bench on the side of a valley, an asymmetrical ridge and similar features, all have meaning and invite interpretation.

Everyone may experience pleasure in seeing the beautiful colors, the symmetrical forms, or even the fantastic shapes in scenic features but if one may also interpret and decipher the origin and history of these features, how much greater the pleasure and satisfaction derived, and the increased appreciation of the scenic features.

The Grand Canyon of the Colorado as a scenic feature is beautiful in color of rock material and impressive in magnitude, but the Grand Canyon as the work of the river which occupies it; downcutting and dissecting during 10 to 20 million years; exposing in this downcutting, rock units which differ in lithology, in structure, age and origin; rock units which by enclosed marine fossils record periods of sea incursion; rock units which by other characteristics record deposition in arid land conditions; periods of mountain building when rock strata were tilted, faulted, metamorphosed and intruded with igneous lavas; periods of long continued erosion when great thicknesses of rock strata were worn away and large areas reduced to level peneplains; when one sees all this in the rocks of the Grand Canyon, involving a duration of perhaps a billion and a half years, how much more impressive, how much more awe-inspiring the Grand Canyon becomes.

[1]Address of the retiring President of the Ohio Academy of Science, delivered at the annual meeting of the Academy held in Columbus, May 3, 1946. The publication of the illustrations accompanying this paper is made possible by a grant from the John A. Bownocker Endowment of the Department of Geology, The Ohio State University.

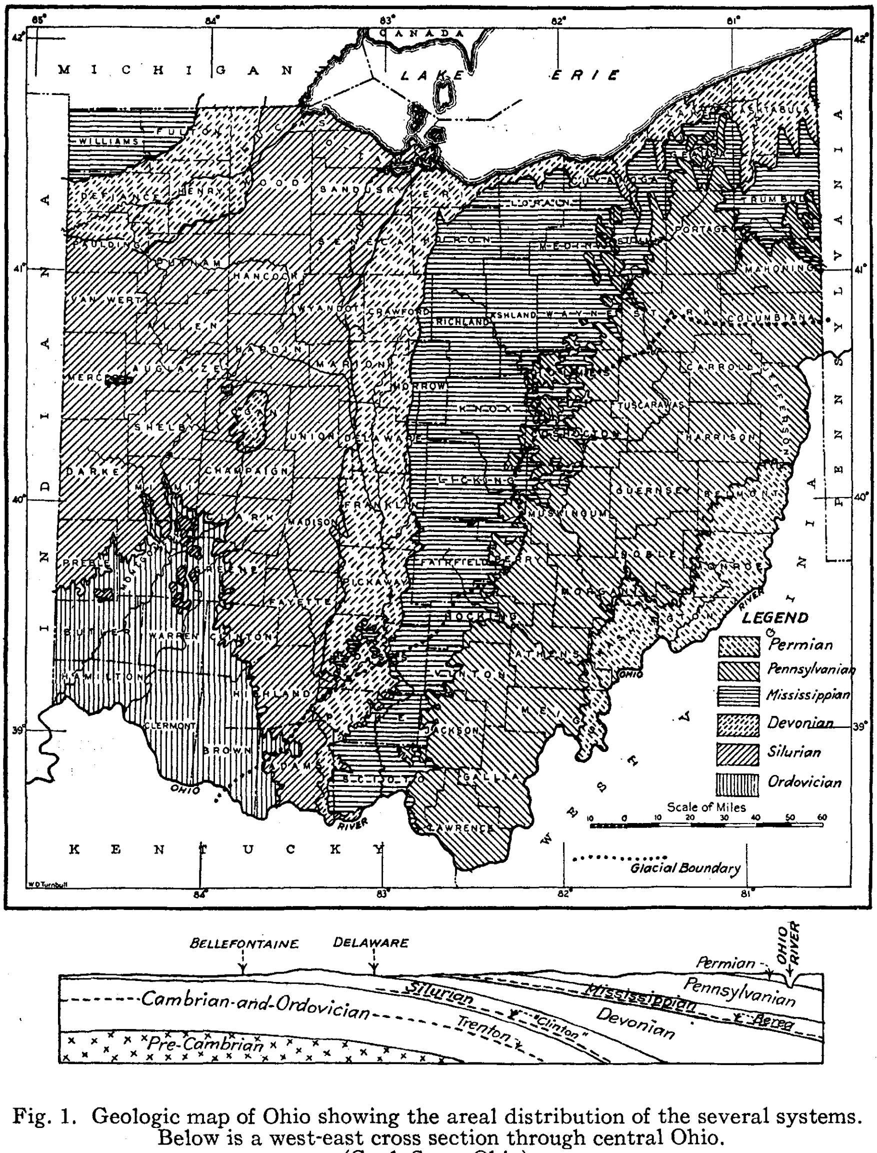


Fig. 1. Geologic map of Ohio showing the areal distribution of the several systems. Below is a west-east cross section through central Ohio. (Geol. Surv. Ohio).

SOME BASIC FACTS AND PRINCIPLES

The larger units of the standard time scale are shown in Table I, those units present in Ohio being in *italics*. All the bedrock units exposed in Ohio are of Paleozoic age, the third or middle one of the five great eras are of geologic time. The exposed rock strata range from Ordovician, the second period of the Paleozoic, to Permian, the last period of the Paleozoic.

TABLE I

GEOLOGIC TIME SCALE

Era	*Period*	*Estimated Duration in Years*
CENOZOIC	*RECENT*	25,000
	PLEISTOCENE (Glacial)	1,000,000
	TERTIARY	60,000,000
MESOZOIC	CRETACEOUS	65,000,000
	JURASSIC	35,000,000
	TRIASSIC	35,000.000
PALEOZOIC	*PERMIAN*	25,000,000
	PENNSYLVANIAN	45,000,000
	MISSISSIPPIAN	40,000,000
	DEVONIAN	50,000,000
	SILURIAN	40,000,000
	ORDOVICIAN	85,000,000
	CAMBRIAN	70,000,000
PROTEROZOIC		650,000,000
ARCHEOZOIC		650,000,000

The distribution of the several rock systems as they appear at the surface in Ohio is shown on Figure 1. The rudely belted arrangement of outcrops is due to a long north-south upward fold or anticline, with the axis extending through western Ohio from just east of Cincinnati to the western part of Lake Erie. This fold, called the Cincinnati anticline, is the dominant structural feature in the geology of Ohio. It is a very broad fold with very gentle dips to the east and west, commonly about 40 feet drop per mile. The general features of this anticline are shown by the cross section sketch at the base.

The older rocks, the Ordovician and the Silurian, crop out along the axis of the anticline. As these older systems dip off to lower levels to the east, successively higher and therefore younger systems, appear at the surface and in turn dip eastward beneath younger strata. The same relations exist to the west of the axis but that is largely beyond the state boundary.

A column of principle rock formations exposed in Ohio is shown in Table II, grouped by systems. The three lower systems, Ordovician, Silurian, Devonian, are dominantly limestone. The three higher systems, Mississippian, Pennsylvanian, Permian, are dominantly sandstone and shale.

TABLE II

PRINCIPAL ROCK FORMATIONS OF OHIO

	Thickness Feet
Permian system	
Green sh.—ss. (many members)	400
Washington sh.—ss. (many members)	225
Pennsylvanian system	
Monongahela sh.—ss.—ls.—coal (many members)	250
Conemaugh sh.—ss.—ls. (many members)	400
Allegheny sh.—ss.—ls.—coal (many members)	200
Pottsville sh.—ss.—ls.—coal (many members)	250

Mississippian system	
Maxville ls	25
Logan sh.—ss. (three members)	200
Cuyahoga sh.—ss. (three members including Black Hand)	300
Sunbury sh	25
Berea ss	50
Bedford sh	75
Devonian system	
Ohio sh. (three members)	600
Olentangy sh	35
Delaware ls	35
Columbus ls	90
Detroit River dol. (four members)	200
Sylvania ss	40
Silurian system	
Bass Island dol. (four members including Put-in-Bay)	300
Cedarville dol	200
Springfield dol	10
Euphemia dol	10
Osgood sh	35
Dayton ls	10
Brassfield ls	35
Ordovician system	
Richmond sh.—ls. (several members)	275
Maysville sh.—ls. (several members)	200
Eden sh.—ls. (several members)	200
Cynthiana sh.—ls. (several members)	100

The exposed bedrocks of Ohio are all sedimentary rocks, that is made from sediments, deposits such as clay, sand, calcareous ooze, laid down in shallow marine seas which covered the region that is now Ohio, and later cemented to form solid bedrock.

That division of geology which treats of the surface features of the earth and their interpretation is known as geomorphology. In the language of the geomorphologist the interpretation of surface features is based on structure, process, and stage.

Structure includes the rock material; its resistance, its stratification and jointing, as well as the position of the rock strata, whether horizontal, inclined, folded or faulted.

Process refers to the processes which are working upon the rock materials and thereby producing changes in the surface features. These processes are weathering, erosion, degradation, aggradation. They are the work of dynamic agents such as running water in streams, moving ice in glaciers, wind.

Stage is concerned with the extent to which the change has progressed as compared with the final condition that can be attained by the work of the process involved. It is based upon the principle that a process or set of processes affecting a particular region will change the relief features in an orderly way from one set of characteristics to another set of characteristics until finally the region is brought to a condition in which the agents involved can produce no further changes. The cycle has then been completed. The characteristics of the relief features of the various stages of the cycle are distinctive and thereby determine the stage in the cycle. For most geomorphic cycles the stages are designated by the very general terms of youth, maturity, and old age as based on characteristics and not on actual length of time.

The idea of cycle may be illustrated by the stream-erosion cycle using the diagrams shown in Figure 2. A relatively level surface at considerable elevation above sea level is dissected by a set of streams. Downcutting is rapid, resulting in deep, narrow, steep-walled valleys. Between the valleys are broad level upland areas as yet undissected. The region is in the youthful stage of the stream-erosion cycle (Fig. 2, B, C).

Finally, the streams cut down, to or near to base level which is determined by the level of the body of water into which they drain. The stream gradients become gentle, the rapids and falls have been destroyed, and downcutting stops. Valley widening continues, the valley slopes become gentler, and the upland flats become narrower until only ridges remain. All the surface is now in slopes. The dissection is complete. The region is in the mature stages of the erosion cycle (Fig. 2, D).

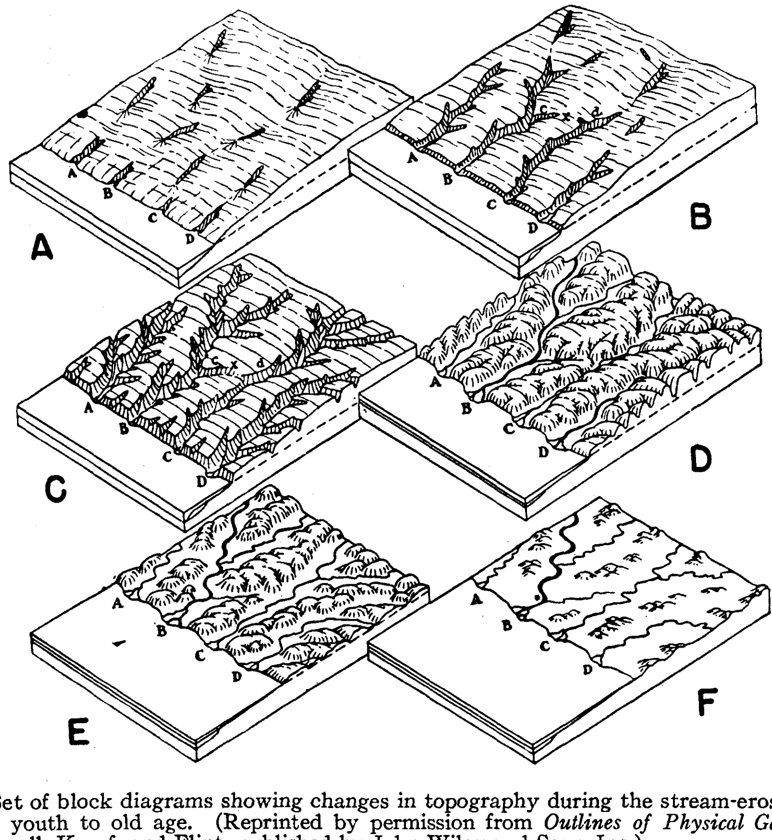


Fig. 2. Set of block diagrams showing changes in topography during the stream-erosion cycle from youth to old age. (Reprinted by permission from *Outlines of Physical Geology*, by Longwell, Kropf, and Flint, published by John Wiley and Sons, Inc.)

Further erosion lowers the divide ridges making the valley slopes still gentler, floodplains develop and increase in width, until all the region has been lowered to the lowest possible level, the base level of stream erosion, an even, lowland plain. The region has reached the old age stage of the stream-erosion cycle, and no further stream erosion may take place. The cycle has been completed (Fig. 2, F). During the process of stream erosion, the region has passed from a level upland plain, to a rugged, completely dissected country all in slopes, and finally again to an even plain but at a lowland level. This is the history and the fate of every region upon which rain falls and which has sufficient elevation above sea level.

The locations of a number of the scenic features or interesting relief features of Ohio are shown on Figure 3. These features are of various types and origins. The largest number has resulted from the work of running water; others from the work of ground water; others from glaciation. Only a few of these can be treated in

Fig. 3. Map of Ohio showing the location of scenic features.

this paper for it seems that our purpose can be better served by a full treatment of a small number than by a more general treatment of a large number. We will treat first a group located in northern Greene County, second a group in western Hocking County, and third Lake Erie and the islands.

GORGES OF GREENE COUNTY

In northern Greene County, about 10 miles south of Springfield, there are three rather notable steep-walled gorges located respectively near the villages of Clifton, Yellow Springs, and Cedarville, all within a radius of three miles (Fig. 4). The largest, most prominent one of these is Clifton gorge and this one will be treated as an example of the group. It illustrates admirably the relation of the form of the valley to the several rock formations in which it is cut.

Clifton Gorge is part of the Little Miami River Valley, located west of the village of Clifton (Fig. 4). Northeast of Clifton the Little Miami flows in a very broad, upland valley cut in glacial drift as shown in unit 1 of Figure 5. It served as an outlet for the melt waters of a considerable section of the glacier front to the north and east and its broad valley floor is underlain by gravel. Except for its greater width it is a typical stream valley of the glacial region of central Ohio.

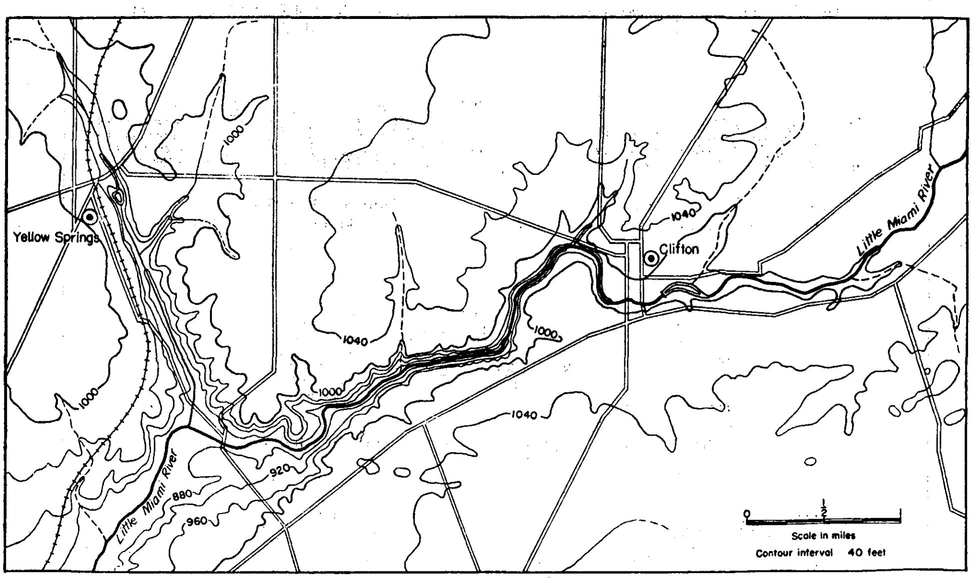


Fig. 4. Map of the Little Miami River Valley in the Clifton-Yellow Springs region.

Just east of Clifton the river reaches the bedrock and the valley deepens rapidly so that in half a mile downstream at the west edge of the village, the valley is about 50 feet deep and has a cross section as shown by unit 2 of Figure 5. The gradient of the river is steep and its work is almost entirely downcutting. The valley sides are steep to overhanging and the valley width is little more than the width of the stream (Fig. 6). It is a typical youthful valley formed by rapid downcutting in a massive rock of uniform resistance.

Just west of the bend west of the village the river drops into a narrow, winding channel and plunges down by a series of rapids for a drop of 20 to 30 feet in a distance of about 50 yards (Fig. 7). The channel is only 5 to 10 feet wide and 10 to 20 feet deep and is cut in the bottom of an outer gorge which in cross profile is a continuation of unit 2. The narrow, twisting channel has apparently been made by enlarging and connecting a series of potholes. This is unit 3 of the cross sections of Figure 5.

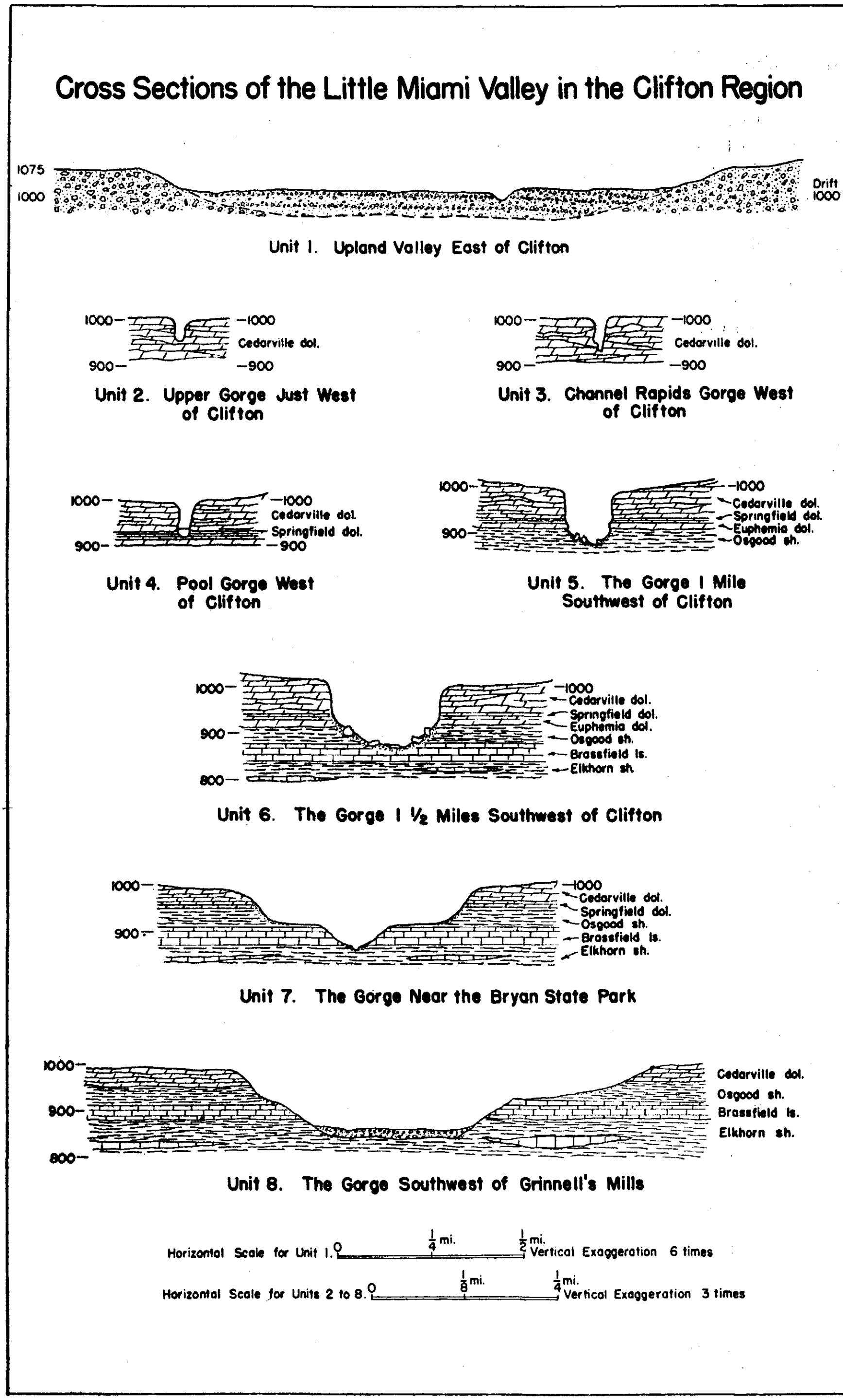


Fig. 5. Cross sections of the Little Miami River Valley in the Clifton region.

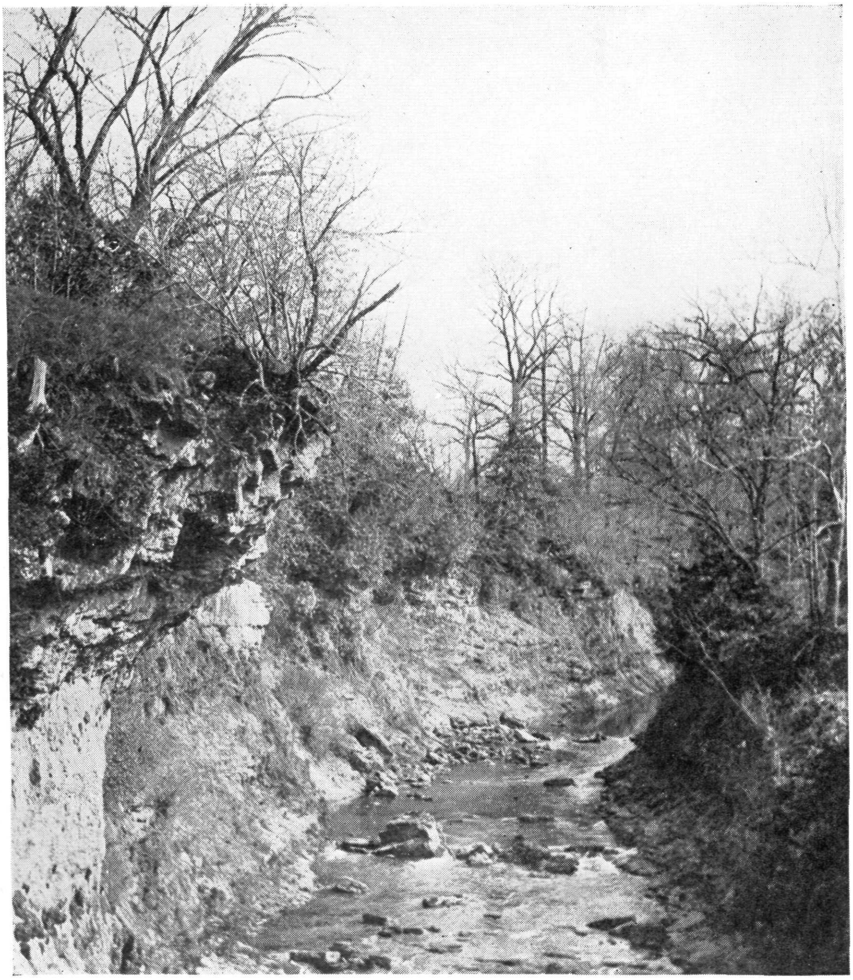


Fig. 6. The upper part of the Little Miami Gorge just west of Clifton.

Fig. 7. View looking up the Channel-Rapids Gorge from the upper part of the Pool Gorge. The Little Miami River just west of Clifton, (Ohio Development and Publicity Commission).

The water next enters a pool and flows quietly for about 200 yards in a narrow gorge 60 to 70 feet deep, and only 50 to 60 feet wide, with vertical or overhanging walls. This is unit 4 of Figure 5. It has a width similar to that in unit 2, and the upper, outer part of unit 3 but it is deeper and the walls rise direct from the water level of a quiet pool which fills the entire width of the gorge.

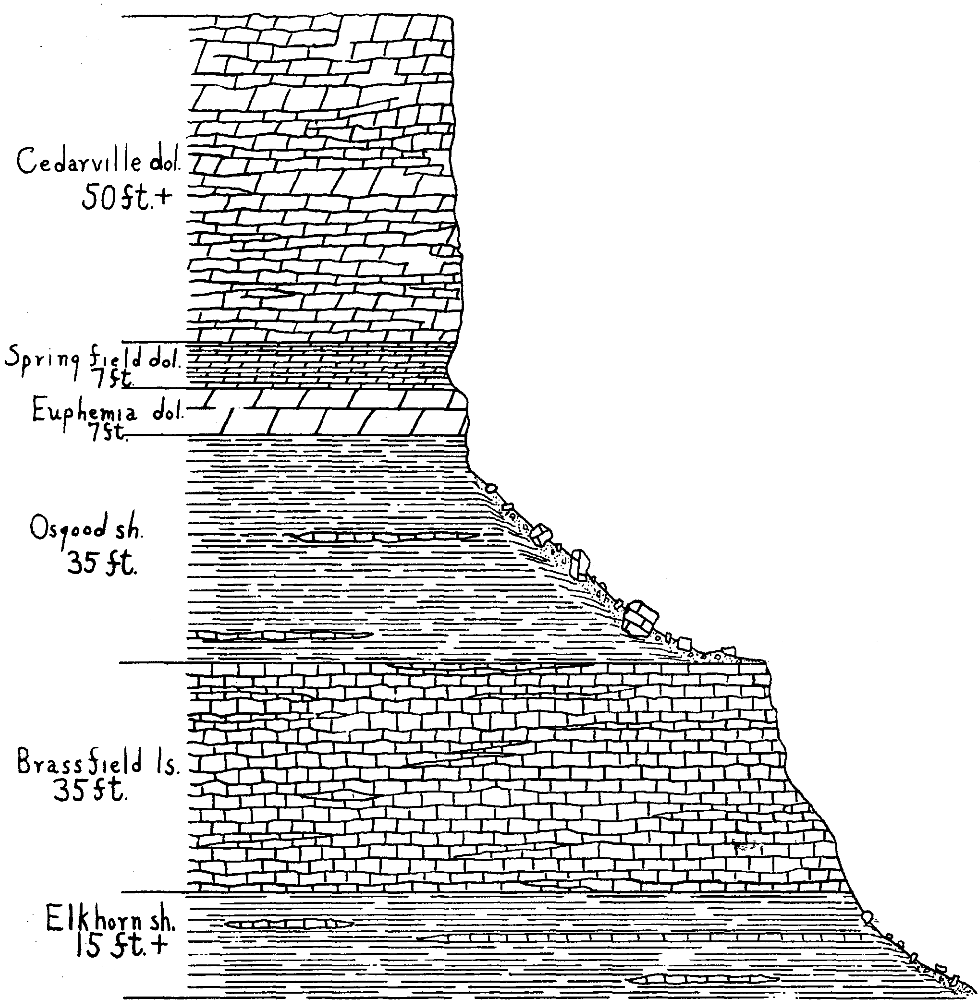


Fig. 8. Columnar section of the rock formations of the Little Miami River Gorge.

All the rock exposed in the gorge through units 2, 3, and 4, is massive, porous dolomite in ledges 5 to 10 feet thick. It is known to geologists as the Cedarville dolomite and is shown as the highest unit of Figure 8. It commonly forms bold, vertical cliffs and narrow gorges with high-gradient streams. Next below the Cedarville is the Springfield dolomite, 5 to 10 feet of bedded stone in even layers 4 to 10 inches thick (Fig. 8). It is less resistant than the Cedarville and at places weathers out forming a slight reentrant beneath the Cedarville cliff. Next below is the Euphemia dolomite, 5 to 10 feet of thick-bedded stone (Fig. 8). It is more resistant than the Springfield and at places forms a slight shoulder on the slope. At places both the Springfield and the Euphemia unite with the thicker Cedarville above in one great cliff face.

Below the Euphemia is about 40 feet of soft, blue shale, with a few layers of shaly limestone, known as the Osgood shale (Fig. 8). This unit weathers readily, and slumps away on the valley side leaving the dolomite above insufficiently supported so that the Euphemia and higher dolomites break off in great blocks that fall onto, and become part of the talus slope below, which covers the outcrop of the Osgood shale. By this method of slumping away of the shale, and the falling away of the unsupported dolomite, the cliff faces retreat and the valley is widened at the level of the shale.

Below the Osgood is the Brassfield limestone, a firm, bedded stone about 30 feet thick (Fig. 8). Where the river has cut into the Brassfield limestone, there is an inner narrow valley or gorge and the river gradient is steep.

Beneath the Brassfield limestone should be the Elkhorn, a soft, clay shale which weathers readily (Fig. 8). It is not exposed in the gorge, but its presence is plainly indicated by the broader valley floor down stream from the ouctrop of the Brassfield.

Returning to the Pool Gorge of unit 4 it may now be noted that the base of the massive Cedarville dolomite is at or just below the water level of the pool (Fig. 5, unit 4) and that the basin occupied by the pool was dug out from the underlying less resistant, thin-bedded Springfield dolomite. This allowed the Cedarville dolomite to break off along vertical joints to form such vertical gorge walls as shown in Figure 9 with a reentrant at the base made by the wearing out of the less resistant thin-bedded Springfield dolomite.

Continuing down stream from the Pool Gorge, unit 4, the valley broadens gradually and becomes deeper to 100 feet and ultimately to 150 feet (Fig. 5, unit 5). The upper 40 to 50 feet of the bluff is a cliff of massive Cedarville dolomite and below this is a steep talus slope with large loose blocks of Cedarville, down to river level (Fig. 10). Many of the blocks are of enormous size, up to 20 to 30 feet across and many of them lie with the bedding planes at various angles. One great block, known as "Steamboat Rock" and shown as Figure 11, stands in the middle of the river with the bedding planes in a vertical position. The river is cutting at some level in the Osgood shale and downcutting and valley widening are rapid.

This unit 5 of the valley has a length of about half a mile. It is a region of distinct scenic beauty as well as geologic interest. The bluffs of massive dolomite; the fern-covered talus slopes with great projecting blocks of stone; the rapid flowing stream; the tall treees rising straight toward the sunlight above the gorge; all combine to form a scenic feature which is unsurpassed in western Ohio.

Another considerable section of the gorge is represented by unit 6 of Figure 5. It differs from unit 5 chiefly in that the downcutting river has here reached the top of the more resistant Brassfield limestone, and has carved out a broader valley floor near the stream level on the top of the limestone. Also the valley as a whole is broader and the talus slopes longer and gentler.

Farther down the valley the river has cut into the Brassfield limestone forming an inner, relatively narrow, steep-sided valley as shown in unit 7 of Figure 5. At the top of the Brassfield there is a narrow rock bench, the rock floor level of unit 6. Above this on the outcrop of the Osgood shale, is the usual talus slope with blocks of dolomite from above. The Cedarville dolomite, here reduced to 10 to 20 feet thickness, forms the usual bold vertical cliff capping the valley slope.

Farther down the valley, near the mouth of Yellow Springs Creek, the Little Miami Valley floor widens to about one-fourth of a mile, as shown in unit 8 of Figure 5. Here the river has evidently cut through the Brassfield limestone and

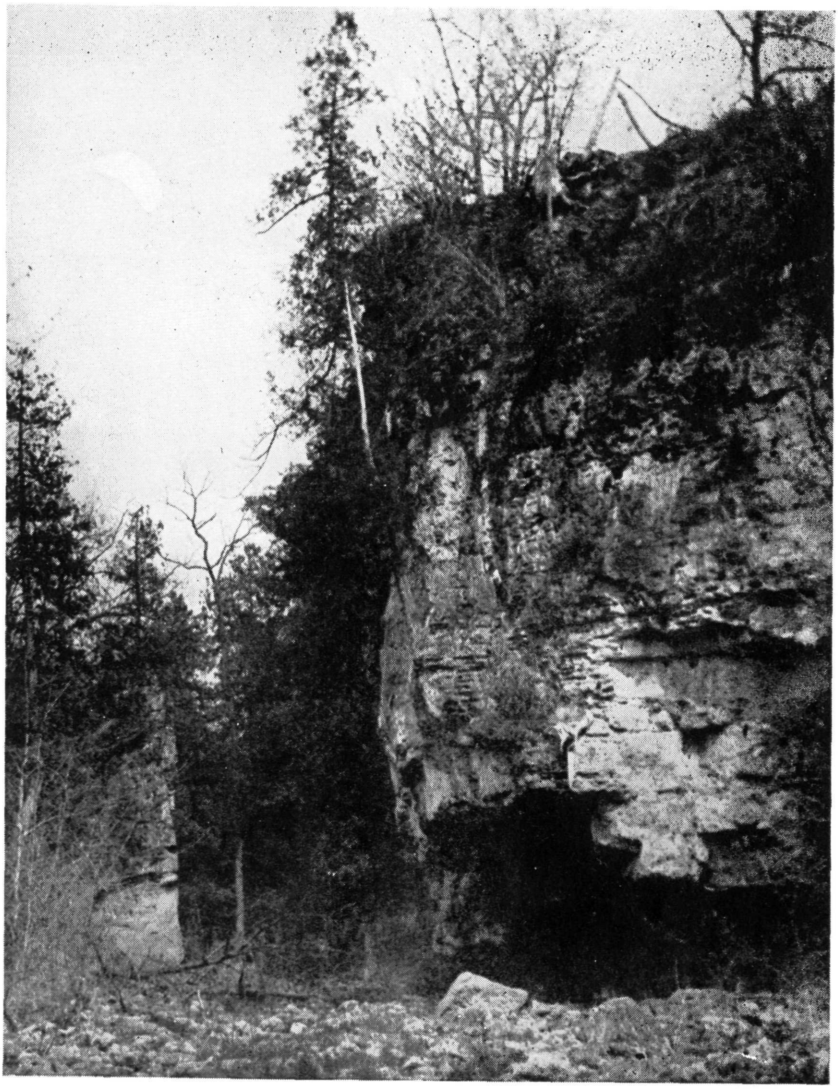


Fig. 9. Bluff of Little Miami Valley at the downstream end of the Pool Gorge. The cliff is Cedarville dolomite and the reentrant at the base is caused by the wearing out of the less resistant Springfield dolomite.

Fig. 10. The Little Miami River in Clifton Gorge showing blocks of massive Cedarville dolomite that have fallen from the cliffs above. (Ohio Development and Publicity Commission.)

Fig. 11. "Steamboat Rock" on the Little Miami River in Clifton Gorge. A block of Cedarville dolomite with bedding planes in a vertical position.

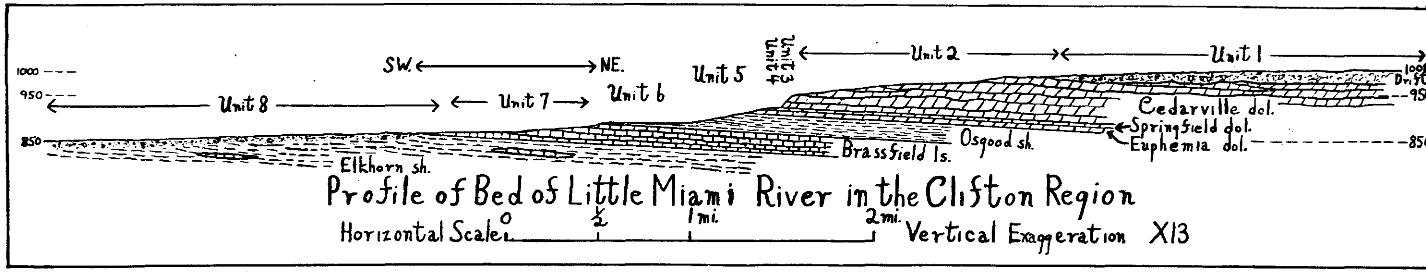


Fig. 12. Longitudinal section and profile of bed of Little Miami River in the Clifton region, showing the relation of the gradient of the stream to the bedrock material.

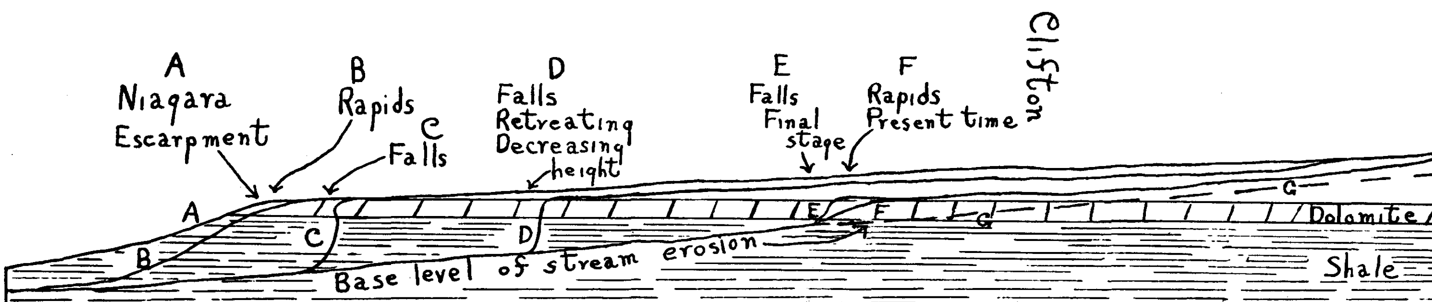


Fig. 13. Longitudinal section and profile along the Little Miami River showing successive stream profiles during the origin, retreat and disappearance of the falls.

widened the valley in the horizon of the Elkhorn shale, although no exposures of the Elkhorn are known for several miles farther down the valley. The steeper slope above is on the outcrop of the Brassfield limestone. The bench and gentler slope next above are on the outcrop of the Osgood shale. The steeper slope at the top of the valley wall is on the outcrop of the higher dolomites.

There is also a close relation of the profile of the river bed to the underlying rock materials as shown in Figure 12. Unit 1 is on the upland where the river flows with gentle gradient on glacial drift. In unit 2 the river is flowing on the Cedarville dolomite and the valley is deepening rapidly. Unit 3 is the rapids by which the river crosses the lower part of the Cedarville dolomite down into the plunge basin of unit 4 carved out of the underlying Springfield dolomite. In unit 5 the river has a steep gradient down across the soft Osgood shale to unit 6 where the gradient is gentle, held up on the top surface of Brassfield limestone. Unit 7 has a steeper gradient across the Brassfield and unit 8 has a gentle gradient in the Elkhorn shale. The longitudinal profile and the cross profile of the valley in each unit is determined by the nature of the rock.

About three miles west of Clifton near the village of Yellow Springs is Yellow Springs Gorge which is part of the valley of Yellow Springs Creek (Fig. 4). This creek heads out on the glacial plain to the north where it flows in a broad open valley cut in glacial drift. Near the village it reaches the bedrock and descends, by a waterfalls on the Cedarville dolomite, into the head of the gorge which leads southward for about two miles, where Yellow Springs Creek joins the Little Miami River just west of the lower end of Clifton Gorge. The main characteristics of Yellow Springs Gorge and rock units exposed are quite similar to those of Clifton Gorge but less rugged and picturesque.

Small units of Yellow Springs Gorge and of Clifton Gorge are now in parks under various forms of management. The entire two gorges, including the place where they unite, should be acquired by the state in order to preserve this most outstanding scenic feature of western Ohio and make it better available for visit by the public.

The explanation of the origin and the location of these gorges and water falls is connected with certain regional geologic relations of southwestern Ohio and adjoining states which are shown on Figure 14. There is here an elliptical area of Ordovician rocks surrounded by a band of the overlying and therefore younger Silurian rocks. The Ordovician outcrop is on the axis of the Cincinnati anticline and the rock strata dip gently away from the Ordovician to the east and to the west down the flanks of the anticline and also to the north on the plunging axis of the anticline. These relations in so far as southwestern Ohio is concerned are more exactly shown in Figure 15 which gives the distribution of the Ordovician and Silurian systems and the location of the gorges near Clifton in the western part of the Silurian band, that is in the lower part of the Silurian rock section.

The map also shows the drainage pattern of the region, the chief feature being that the streams flow from the northeast, north and northwest and converge toward Cincinnati. This means that the general slope of southwestern Ohio is toward Cincinnati. The streams flow from Silurian to Ordovician, that is from younger to older rocks and opposite to the direction of dip of the strata.

The Ordovician rocks consist of shale and thin beds of limestone and are less resistant than the Silurian rocks which consist largely of thick-bedded or massive limestone or dolomite. The area of less resistant Ordovician rocks, being in the down-stream part of the drainage system, has been worn to a lower level, and to a more rugged topography, than the Silurian area of more resistant rocks on the headwaters region. Where the two area border, there was thus developed a narrow belt with a steeper slope descending from the Silurian area to the Ordovician area as shown in Figure 15. This is an indistinct escarpment slope on the edge of the

Silurian rocks. Since the Silurian rocks dip gently away from the Ordovician area, erosion has developed something of a cuesta form with an undercut-slope facing the Ordovician and a dip-slope toward the Silurian area. Stream erosion

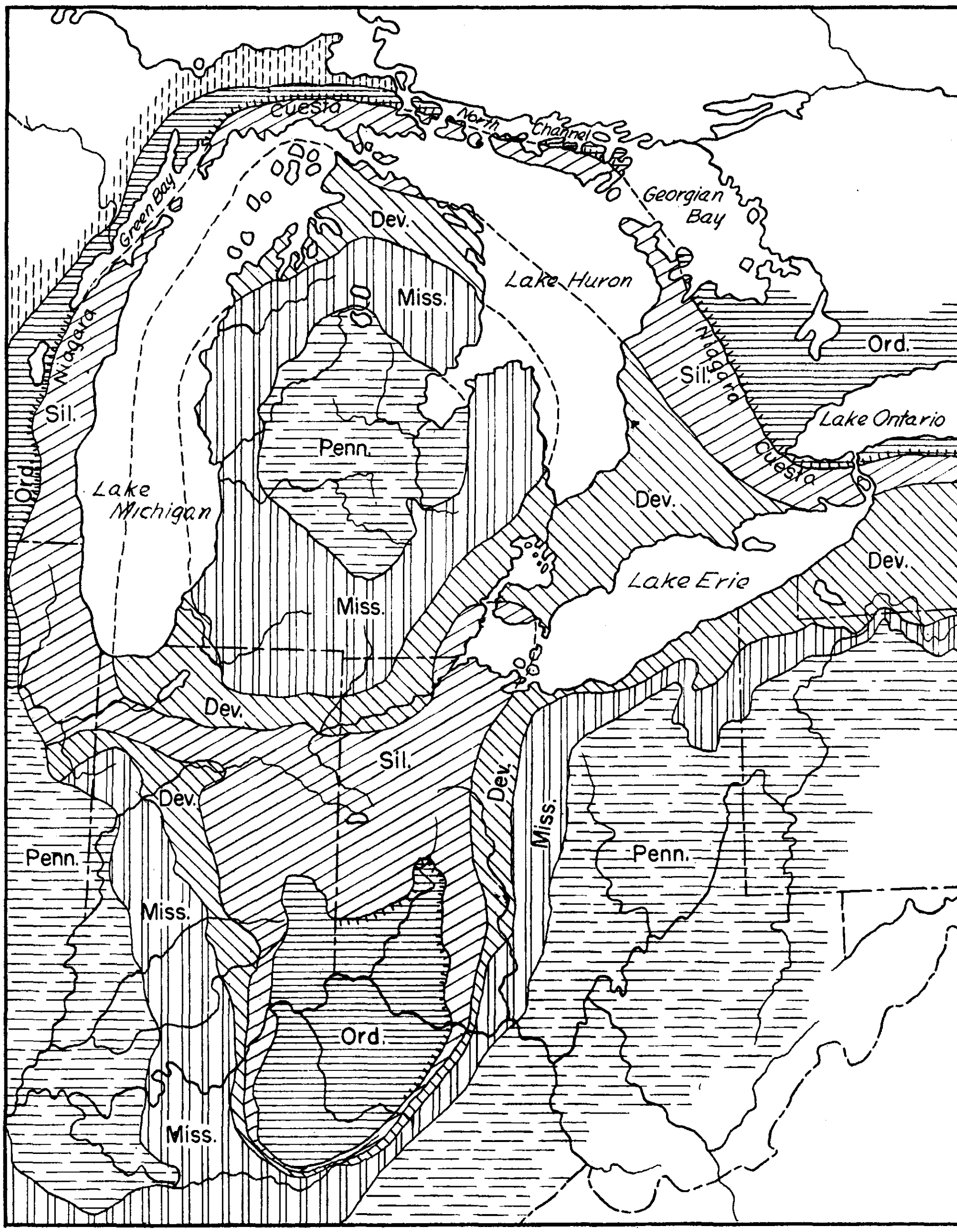
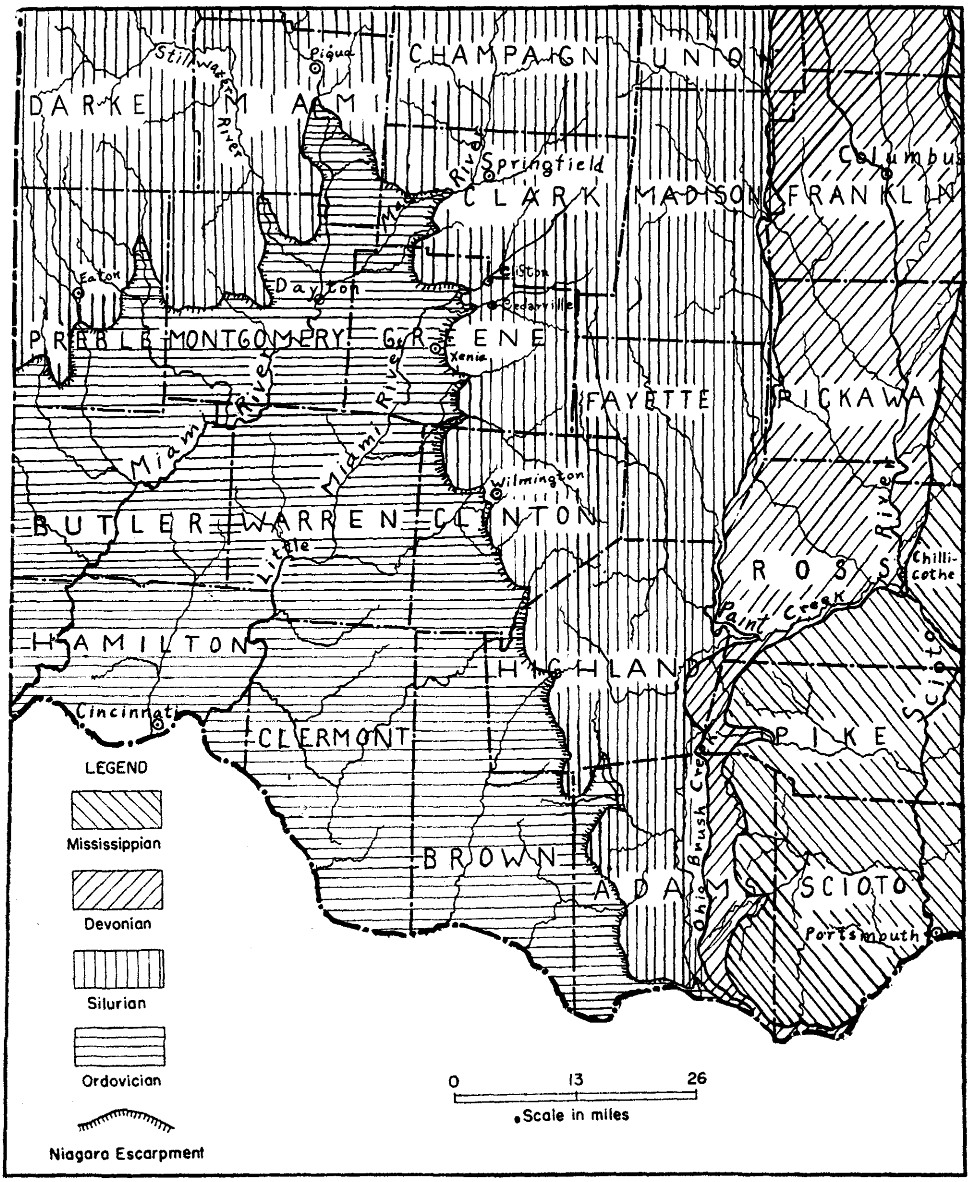


Fig. 14. Geologic map of the Eastern Interior region showing the distribution of rock systems and the course of the Niagara Escarpment.

has made the course of the escarpment irregular (Fig. 15) and the details of this cuesta feature are largely hidden by the mantle of glacial drift that covers the region.

When the glacial ice melted off the surface of southwestern Ohio a southwestward flowing stream came into existence along the present course of the Little



drainage.

Fig. 15. Geologic map of southwestern Ohio showing the distribution of the rock systems, the course of the Niagara Escarpment, and the drainage.

Miami River past Clifton. About four miles southwest of this village the stream passed from the higher surface on the more resistant Silurian dolomites down the escarpment to the lower surface on the less resistant Ordovician shales as shown in Figure 13. The faster down cutting on the shale produced rapids (Fig. 13, profiles A and B) and when the stream bed on the softer shale was worn below the base of the resistant dolomite a waterfalls resulted (profile C). The plunge of the water over the falls wore out the softer shale beneath the edge of the dolomite, and inadequately supported blocks broke off and fell away. This resulted in the gradual retreat of the falls upstream (profiles C and D) and the formation of a gorge in that portion of the valley along which the falls retreated. Since all stream beds must rise upstream, the falls gradually decreased in height to the place where the stream bed rose to the base of the resistant dolomite (profile E). No longer could undercutting or sapping of the cap rock take place. The lengthening of the gorge by the process of the retreat of the falls was ended. This condition was reached for the Little Miami in unit 4, the Pool Gorge. With further erosion the falls became a rapids (profile F). This is unit 3, the Channel Rapids of the present valley (Fig. 7). The rapids is the stage that follows next upstream from where a falls stops retreating. It carries the water from the level of the valley floor above the falls across the thickness of the resistant rock unit that caused the falls. Downcutting is rapid and in course of time even the rapids will be reduced to an even gradient as shown in profile G of Figure 13. That is, in the old age stage of the cycle all irregularities of the gradient of the stream bed due to differential hardness of the rock will have been worn away.

In both the Yellow Springs and the Cedarville gorges the level of the stream at the base of the falls is approximately at the base of the Silurian dolomite and the upstream retreat of the falls will soon cease. With further erosion the falls will become rapids and these will gradually be worn away. This is the history through which all the streams which flow from the Silurian rock areas of southwestern Ohio to the Ordovician rock area have passed.

It is probable that the Little Miami River took its present course across the escarpment with the disappearance of the last ice sheet, the Wisconsin, usually estimated as about 30,000 years ago. During this time the falls has retreated a distance of approximately four miles at an average rate of about nine inches per year.

Similar, but less prominent gorge-like valleys exist to the northwest and west wherever streams across the irregular outcrop of the Cedarville dolomite from Greene County to the Indiana line (Fig. 15). Also to the south of the Clifton region in Greene, Clinton and Highland Counties the valleys become more sharply cut where they cross from the Silurian rocks to the Ordovician.

The escarpment described above is, in topography, in structure, in lithology, and even in the geologic age of the rocks similar to the east-west escarpment of western New York, known as the Niagara escarpment (Fig. 16) and they have had similar effects in the development of gorges and waterfalls.

The Niagara escarpment extends in a curving course from central New York westward through southwestern Ontario, northern Michigan, and eastern Wisconsin, a distance of several hundred miles as shown on Figure 14. Throughout this distance the Niagaran dolomites dip toward the Michigan Basin and form a cuesta ridge with a steep front to the north, northeast or northwest and a gentler slope to the south. Parts of this cuesta are the Niagara escarpment of western New York and southwestern Ontario; the Bruce peninsula; Manitoulin and Drummond islands; a partly buried cuesta ridge in northern Michigan; the Escanaba and Door peninsulas east of Green Bay; and a partly buried, westward-facing cuesta ridge in eastern Wisconsin. Bordering this long elevation, on the north is a long depression worn out on the outcrop band of the Ordovician shales. The lowest parts of this depression form the basins of Lake Ontario, Georgian Bay, North Channel, Green Bay, Lake Winnebago, and the low course followed by the headwaters of Fox River southward in eastern Wisconsin. It is a notable illustration of the influence of rock materials and rock structure in the origin and location of large relief and geographic features.

When the melting of the Wisconsin ice sheet freed the surface of western New York the overflow waters of Lake Erie escaped northward along the course of the present Niagara River (Fig. 16) across a plain underlain by Silurian rocks and dropped off the northward facing escarpment capped by the Niagara dolomites

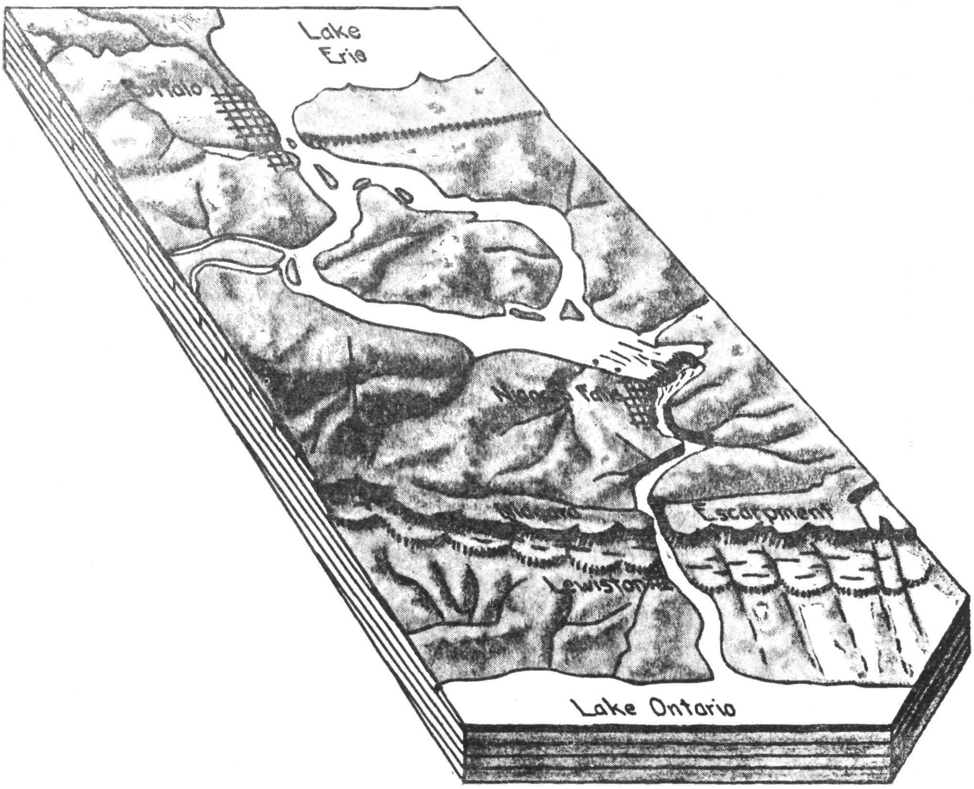


Fig. 16. Bird's-eye view of Niagara River and Falls, looking south. Greatest length of block, 35 miles. Vertical exaggeration, 2 times. (Reprinted from *Outlines of Physical Geology*, by Longwell, Knopf, and Flint, published by John Wiley and Sons, Inc.)

to the lower, Ontario plain underlain by Ordovician shales. The waterfalls thus formed at the face of the escarpment began to retreat upstream by sapping and the fall of the unsupported cap rock, and the Niagara gorge was started. The retreat has continued until now the falls is seven miles from the escarpment where it started, leaving behind the magnificent Niagara gorge. But unlike our Ohio Niagaras there is still plenty of drop and the falls will continue to retreat, and the gorge to lengthen, until perhaps Lake Erie is reached and drained. Lakes and waterfalls are characteristic of the youthful stage of the erosion cycle. Both are short lived features, geologically speaking.

HOCKING COUNTY PARK REGION

In southwestern Hocking County east of Laurelville there are several well known scenic features the locations of which are shown on Figure 17. Of these Ash Cave, Cedar Falls, Old Man's Cave, Conkles Hollow, Rock House, and Cantwell Cliffs are now included in small State Forest Parks. This is a rugged region with a relief of 300 to 400 feet, near the western edge of the Appalachian Plateau.

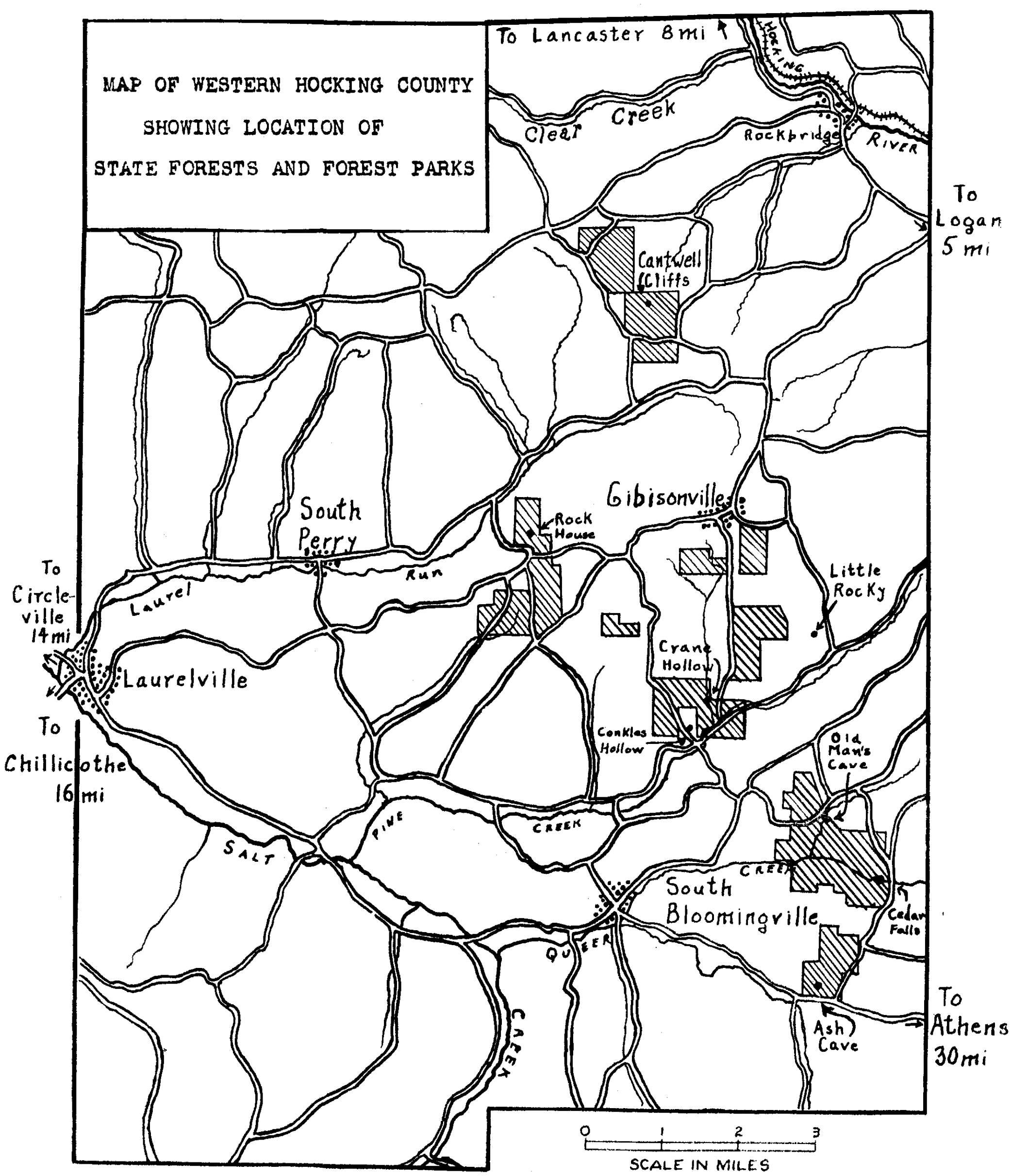


Fig. 17. Map of western Hocking County showing location of state forests and forest parks.

The chief scenic features are narrow, steep-walled gorges which terminate headward in steep-walled, ampitheater-shaped pockets or coves; waterfalls which plunge into these valley heads from projecting ledges above; and rock shelters or re-entrants in the valley walls beneath projecting ledges commonly called caves. All these features are the result of weathering and the erosive work of running water on rocks of differential hardness.

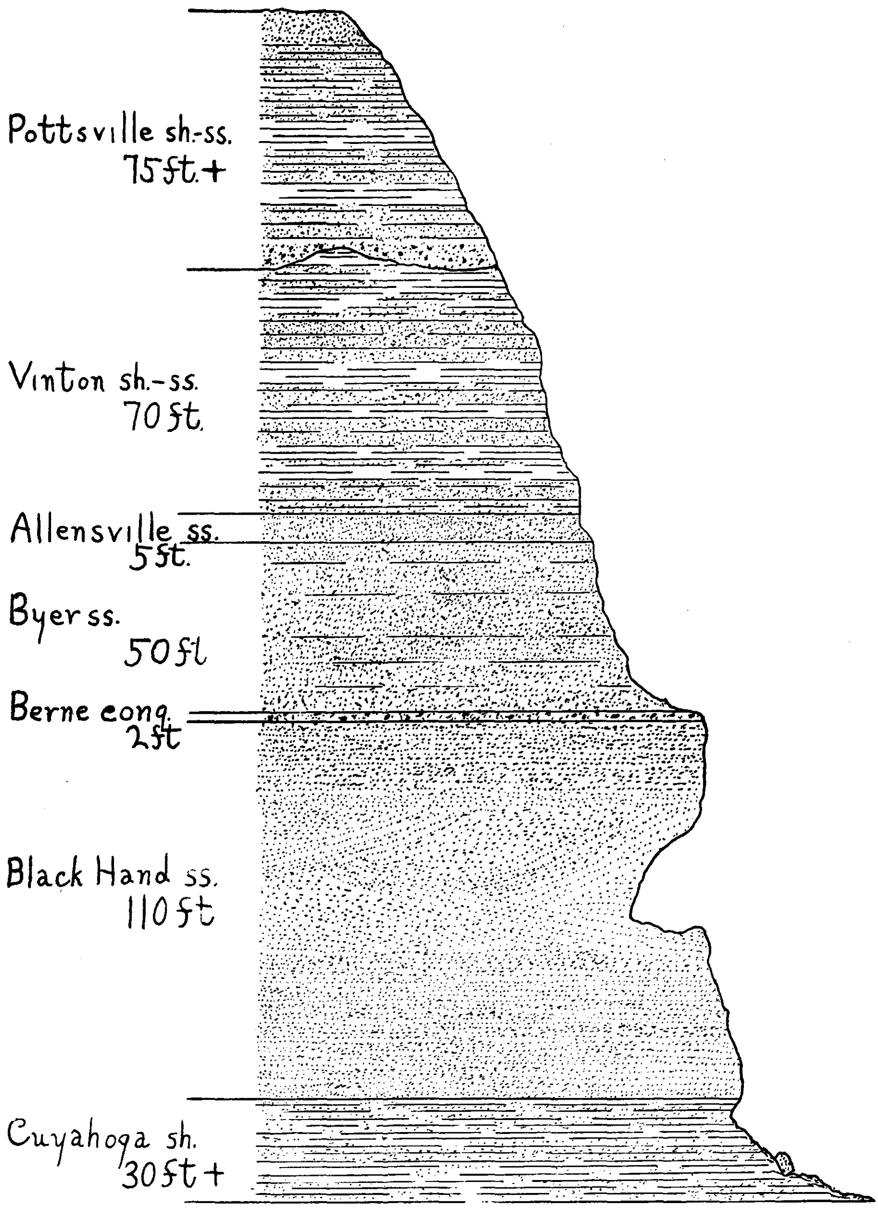


Fig. 18. Columnar section of the rock formations of Western Hocking County.

The rock strata of the region consist of sandstone and shale as shown in Figure 18. The most important unit in the development of scenic features is the Black Hand sandstone, a thick-bedded, massive, resistant, pebbly sandstone 100 to 150 feet thick. If forms the walls of the gorges, causes most of the waterfalls, and in it the valley-side caves are developed. The upper 15 to 20 feet of the sandstone is horizontally-bedded and quite firmly cemented. Lower down, the middle part of the formation is cross-bedded and less firmly cemented. This results in more rapid disintegration of the middle part of the Black Hand and the development of a somewhat projecting upper part of the cliff.

Locally, in this cross-bedded middle part considerable reentrants have developed in the valley walls forming the features called caves, of which Old Man's Cave and Ash Cave (Fig. 19) are the largest and best known. They commonly have a floor on firmer stone below; are semicircular or semielliptical in plan; and half dome shaped with the apex above the middle of the outer edge. Ash Cave has a length of about 500 feet along the face of the cliff; a height of about 80 feet at the top of the dome, and a reentrant depth of about 100 feet at the floor level. These reentrants are believed to be due chiefly to more rapid disintegration locally of the cementing material of the sandstone allowing the grains to fall away. Blocks of sandstone that have fallen from the roof are present, but not numerous. The removal of the sand grains that fall to the floor of a cave may be accomplished by the wind or by the runoff of such rainfall as may be blown into the cave.

It should be noted that these are not true caves; a term that should be reserved for underground caves and passageways developed in limestone rock by solution by ground water. These features are simply reentrants in cliff faces and open out widely to the valley sides. A better name is rock shelter or rock-shelter cave.

Reentrants in the cliffs at the heads of the gorges are in part due to sapping by development of the plunge basin beneath the waterfall, and there are commonly here great blocks of sandstone that have fallen from the projecting ledge above. There should also be here greater decomposition due to the continually moist condition of the cliff from the spray of the waterfall. The sapping action here is important in causing the headward growth of the gorge. It is the usual method of retreat of waterfalls (Fig. 19).

The rock strata of the region dip gently to east as shown in Figure 20. Just west of this park area the Black Hand conglomerate terminates along an irregular, westward-facing escarpment, and the land surface drops down to lower elevation and lower rock units. This is the west edge of the Appalachian Plateau, which here is along the undercut slope of a low angle cuesta on the Mississippian sandstone, particularly the Black Hand sandstone. The drainage is westward so that in general the streams go from the higher upland on the east across the outcrop of the Black Hand to the lower surface to the west or to some valley, the level of which is conditioned by this lower surface. Rapid trenching of the steep slope on the edge of the Black Hand produced waterfalls at some places, and their retreat headward has formed the steep-walled box canyons with ampitheater-shaped heads. Those in which the formative processes are still at work and in which the characteristics are especially well developed, or of large dimensions, are the scenic features.

Certain characteristic topographic features of the region, and their relation to the bedrock, may be shown by a short description and analysis of one of the valleys, such as the valley of Old Man's Creek shown in Figure 22. This creek is 3 miles long and flows southwest to its union with Queer Creek. Six rather distinct physiographic units can be recognized in this valley and are well shown in the longitudinal section and profile of Figure 21. Unit 1 is the headwaters, about half a mile long, and with a gradient at the rate of 250 feet per mile. This is a very typical upland ravine head for this region. Unit 2, 1¼ miles long has a gentle gradient of only 50 feet per mile. Unit 3 is a rapids and waterfall with a total

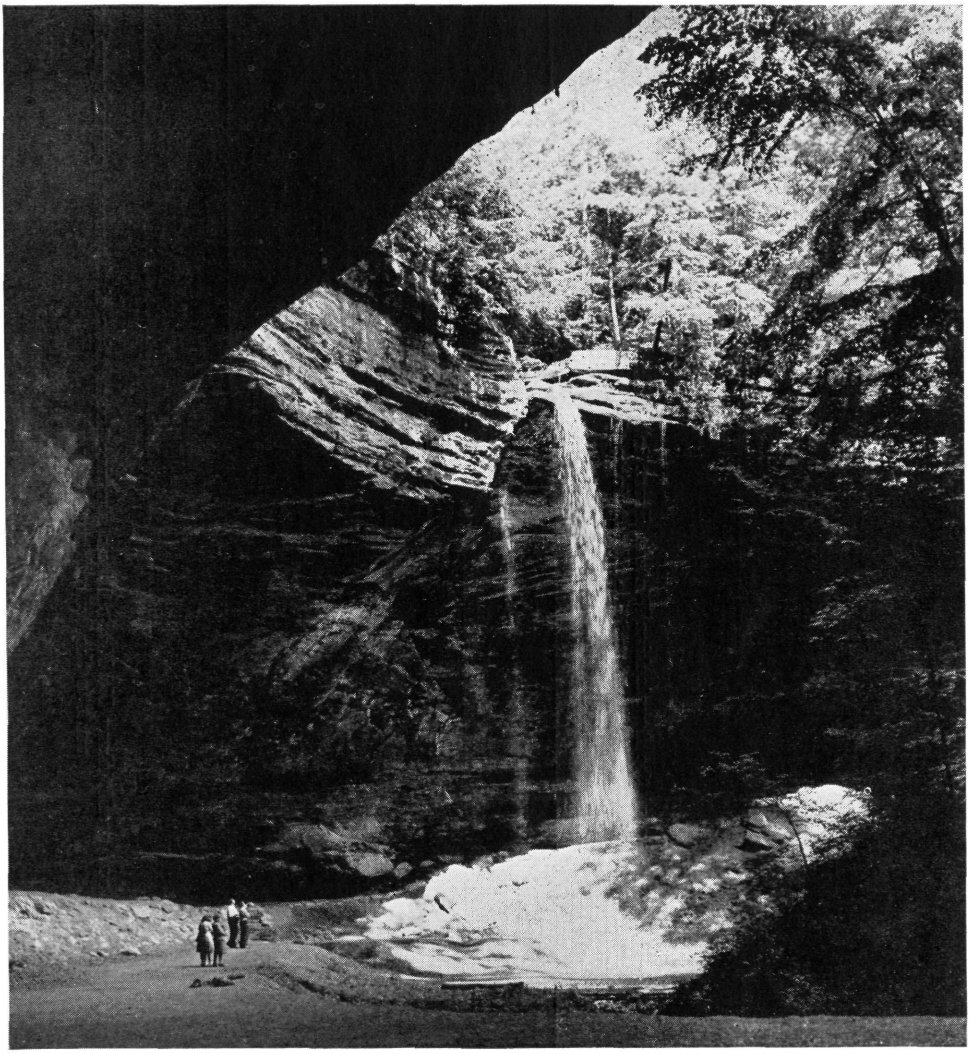


Fig. 19. View of the upper end of Ash Cave, the waterfall, and the plunge basin below. The firm bedded sandstone forms the projecting cliff. The weaker, cross-bedded sandstone is in the upper part of the reentrant behind the falls. (Ohio Division of Forestry. Photo by Bob Wheaton).

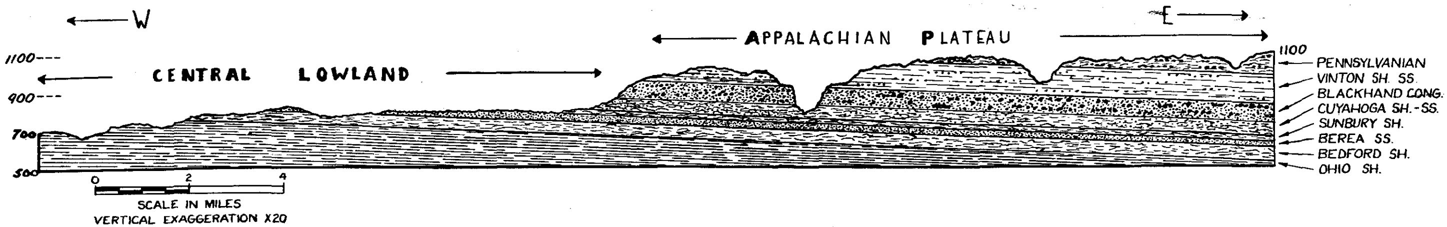


Fig. 20. West to east cross section of the Appalachian Plateau Front in Hocking County, showing the westward facing escarpment and the slight dip to the east.

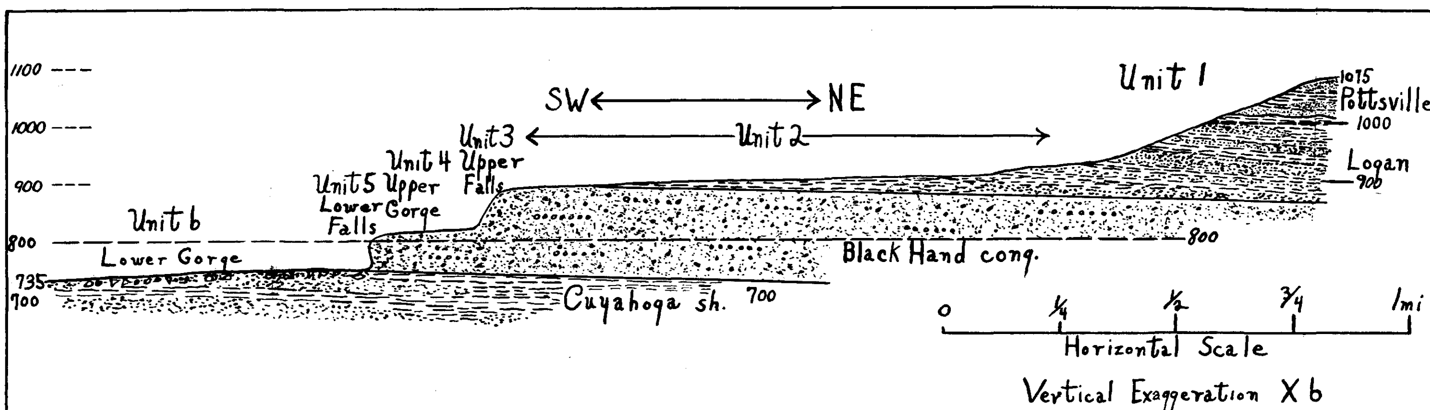


Fig. 21. Longitudinal section and profile along Old Man's Creek, showing the relation of the several physiographic units to the bedrock materials.

descent of 30 to 40 feet by which the stream drops into the head of the upper gorge. Unit 4 is this upper gorge about half a mile long. Unit 5 is the lower falls with a descent of 30 to 40 feet and unit 6 is the lower gorge over 100 feet deep and extending about 1 mile to the union with Queer Creek.

In Figure 23 cross sections of the valley are shown in units 2, 4, and 6. The valley of unit 2, above the gorge is broad and open, about 1 mile wide from divide to divide, 150 to 175 feet deep, and has a valley floor about 100 yards wide (Fig. 23, unit 2). The rocks in which this valley is cut consist of shale, sandy shale, and

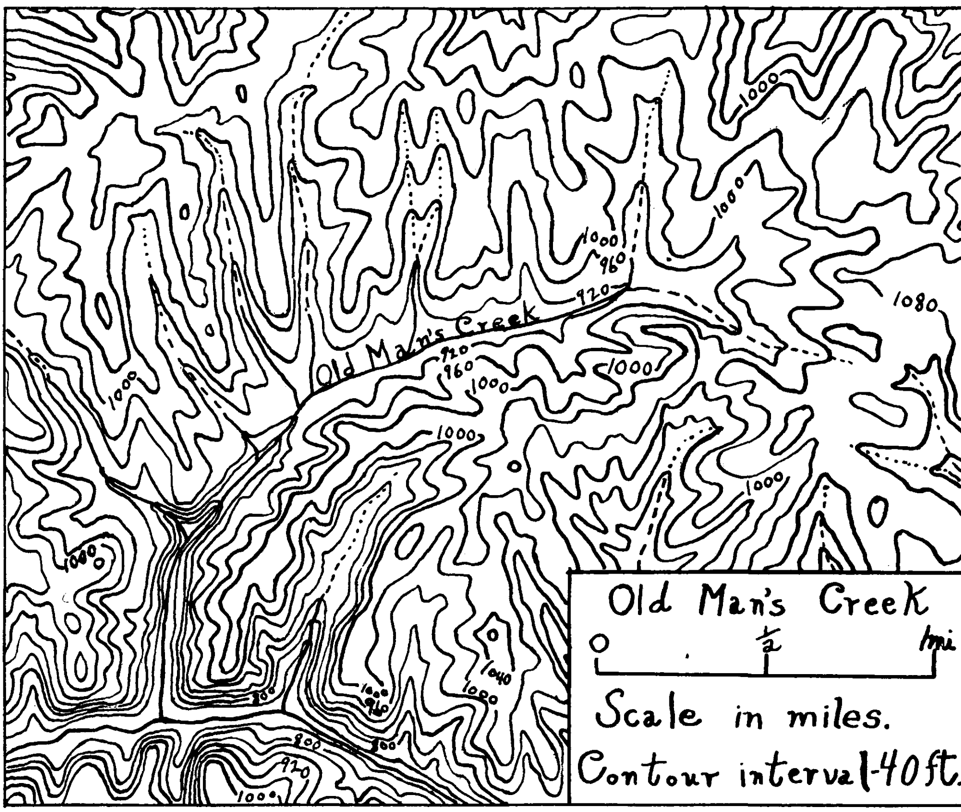


Fig. 22. Topographic map of the area drained by Old Man's Creek, Hocking County.

some sandstone. The floor of the valley is on or slightly above the top of the very resistant Black Hand sandstone, which, by acting as a temporary base level to retard the downcutting, has allowed the widening of the valley and the development of the gentle gradient of this unit. At the lower end of this unit the stream flows for 50 yards on a broad surface of the Black Hand sandstone without a channel as shown in the background of Figure 24. It then descends by a cascade (Fig. 24, foreground) and by a waterfall shown in Figure 25, the whole forming the Upper Falls, unit 3, by which the stream crosses the upper, more resistant part of the Black Hand and enters the head of the Upper Gorge.

Unit 4, the Upper Gorge, increases in depth from 30 to 40 feet near its head, to 60 to 70 feet at its lower end and is cut in the less resistant, cross-bedded, middle part of the Black Hand sandstone (Fig. 23, unit 4). Above this inner gorge is a broad, higher or outer part of the valley with moderate slopes cut in shale and thin-bedded sandstone above Black Hand. This is simliar to the valley of unit 2. On either side of the valley just above the Black Hand is a narrow bench carved out on the upper surface of the Black Hand.

Next follows unit 5, the Lower Falls, shown in Figure 26, by which the water plunges down a twisting channel for 10 to 15 feet and thence falls to a plunge basin below for a total descent of 30 to 40 feet across the lower part of the Black Hand sandstone. At the level of the plunge basin beneath the overhanging ledge fine-grained shaly sandstone is exposed, the top of the next lower rock unit, the Cuyahoga shale.

Unit 6, the Lower Gorge, is over 100 feet deep (Fig. 23, unit 6). The vertical walls include practically the entire thickness of the Black Hand sandstone and the floor is probably in the underlying Cuyahoga shale but a great accumulation of loose material on the valley floor and against the base of the cliffs conceals the basal contact of the sandstone and any lower strata which may have been penetrated. Above the narrow, deep gorge cut in the Black Hand sandstone is the narrow bench or shoulder, and the broad outer valley above, cut in shale and thin sandstone beds. All of this shows a close relation of the form of the valley to the resistance of the rock material.

In the north wall near the lower end of the Upper Gorge, is the well known Old Man's Cave, shown in Figure 27. It is about 200 feet long, along the valley side, about 50 feet high at the top of the arch, and its greatest depth or overhang is about 75 feet. This cave, like the floor of the Upper Gorge, is at the level of the less resistant middle part of the Black Hand sandstone. This less resistant middle part has caused two falls instead of one and two sections of the gorge.

The foregoing has emphasized the contrast of the broad, outer, upper valley with gentle slopes as against the narrow, steep-walled inner gorge (see Fig. 23); the gentle gradient of the valley above the Upper Falls as against the steep gradient of the gorge (see Fig. 21); the falls by which the creek enters the gorge; and the bench on the valley side just above the inner gorge. All these are quite definitely related to, and seem to find adequate interpretation in, the greater resistance of the Black Hand sandstone as compared with the other rock units. If we apply the geomorphic analysis of structure, process, and stage, we find the process, that is stream erosion, is working on varying structure, that is differential hardness of rock units, which has resulted at this stage, in different valley forms according to the different hardness of the rock units.

In the northern part of the Hocking County Park region is a very unusual feature known as Rock House (see Fig. 17). Here is a great cliff of Black Hand sandstone up to 100 feet high forming the south wall of a valley shown in Figure 28. The cliff is quite direct and even, but with certain right angle offsets. At one place the rock mass sets out about 30 feet as shown in Figure 31 but the line of the cliff face is continued into this projecting mass by a tunnel-like passageway 20 to 30 feet wide, 20 to 25 feet high, and about 200 feet long, opening out at both ends. This great corridor is called Rock House. Its existence, its location, and direction, are determined by a joint fracture which runs S. 70° W. and dips steeply to N.W. (Fig. 31). The cliff face of the projecting mass is parallel to the master joint of Rock House and apparently is located on another joint of the same system. The joint fracture cuts the floor of Rock House along the northwest side of the room and cuts the roof along the median line from end to end. The general cross-section form of Rock House is that of a Gothic arch, widest at the base and narrowing to the top into the joint fracture as shown in Figure 29. Certain less resistant beds just above the floor level have apparently caused the wider lower part.

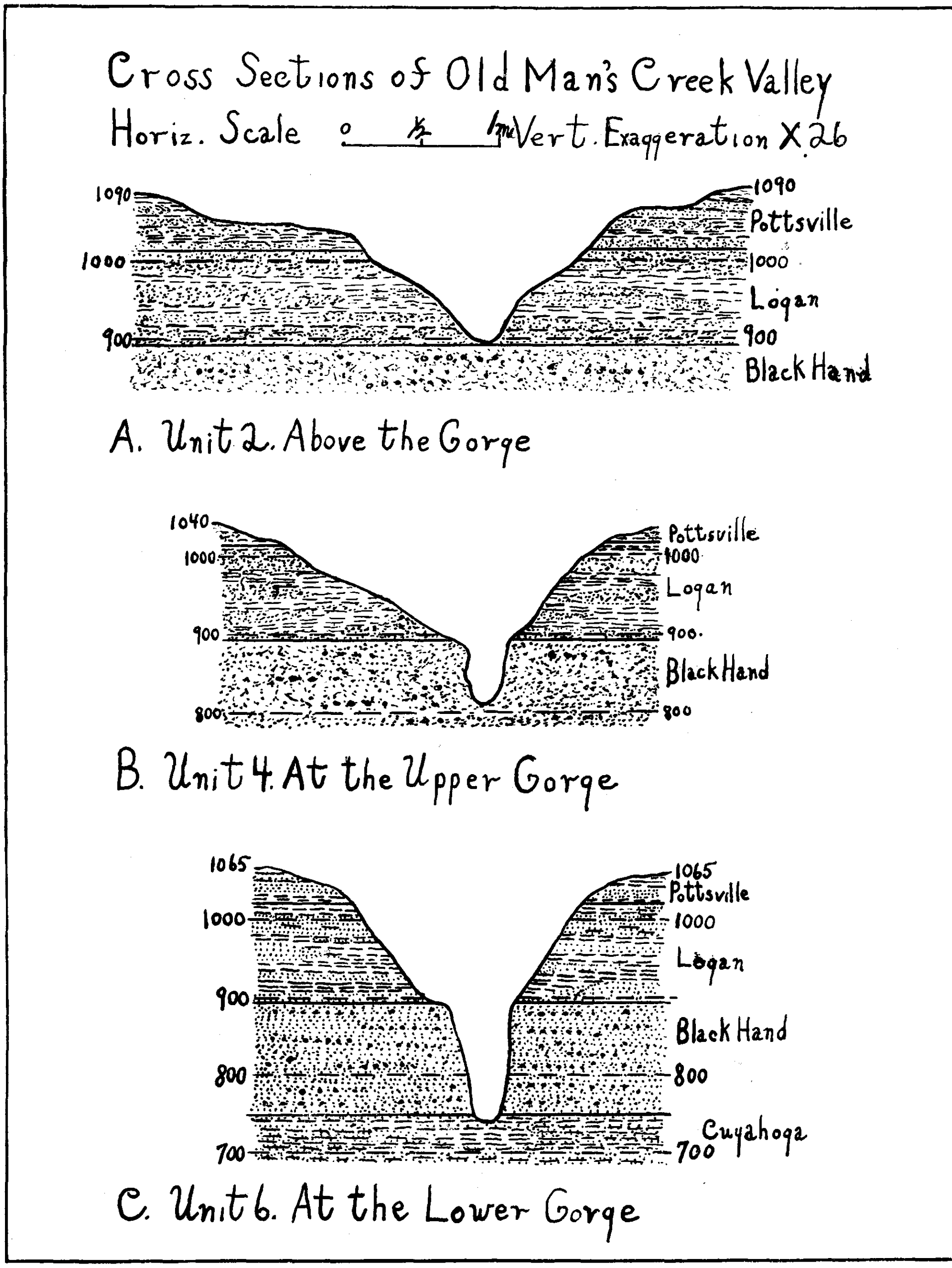


Fig. 23. Cross sections of Old Man's Creek Valley showing the relation of the form of the valley to the lithology of the rock units.

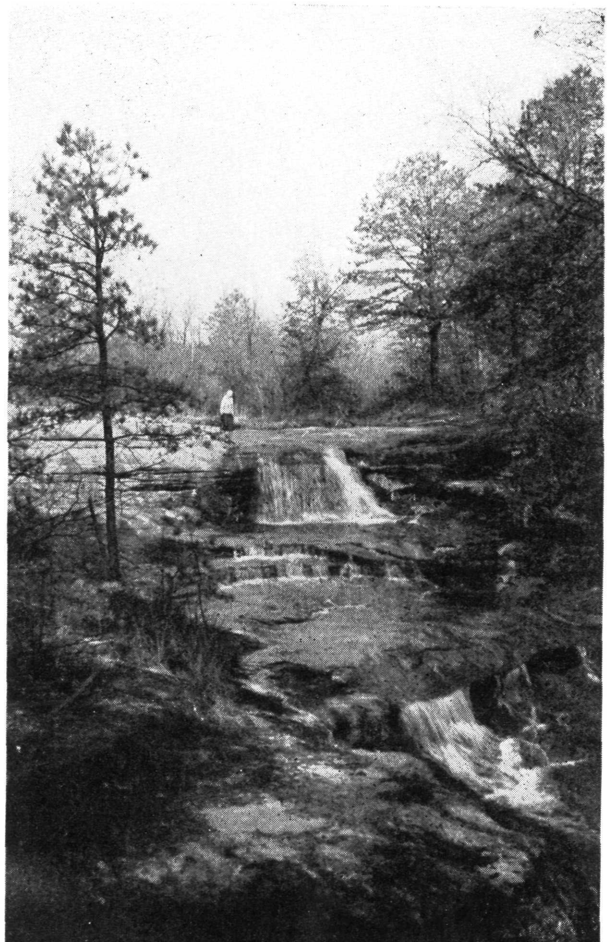


Fig. 24. Old Man's Creek showing in the background the stream spread out on the upper surface of the Black Hand sandstone and in the foreground the cascade at the head of the Upper Falls.

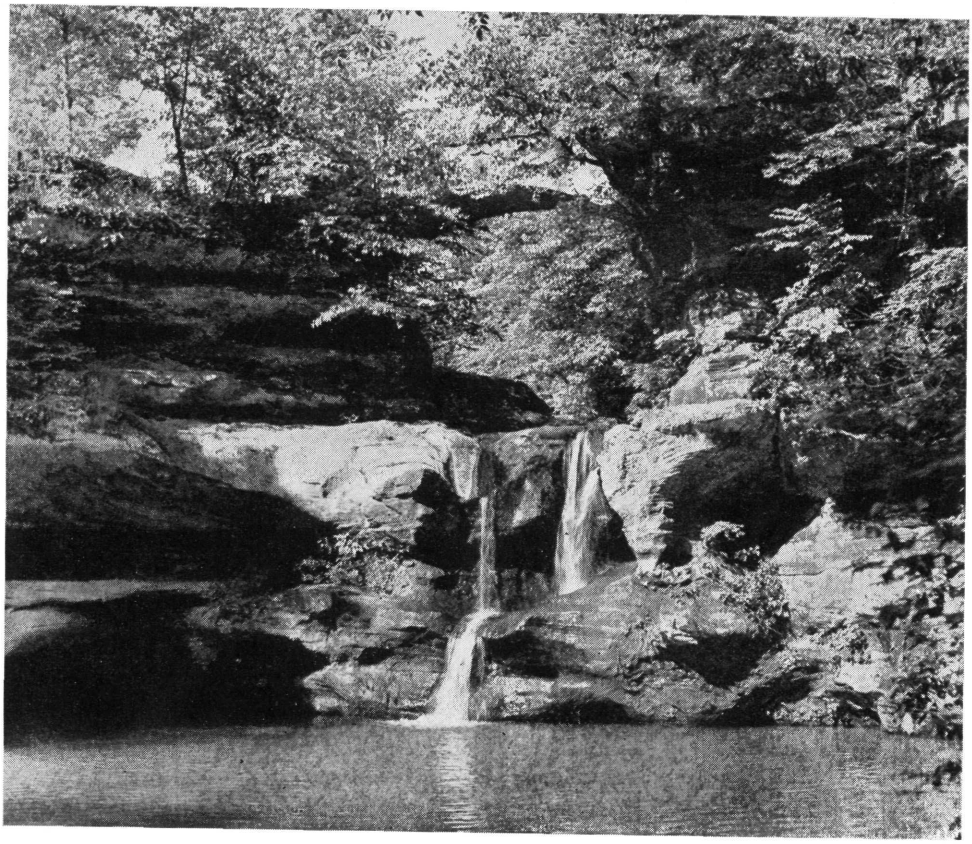


Fig. 25. The Upper Falls by which Old Man's Creek enters the head of the Upper Gorge. The upper part of the Black Hand sandstone is shown. (Ohio Division of Forestry. Photo by Bob Wheaton).

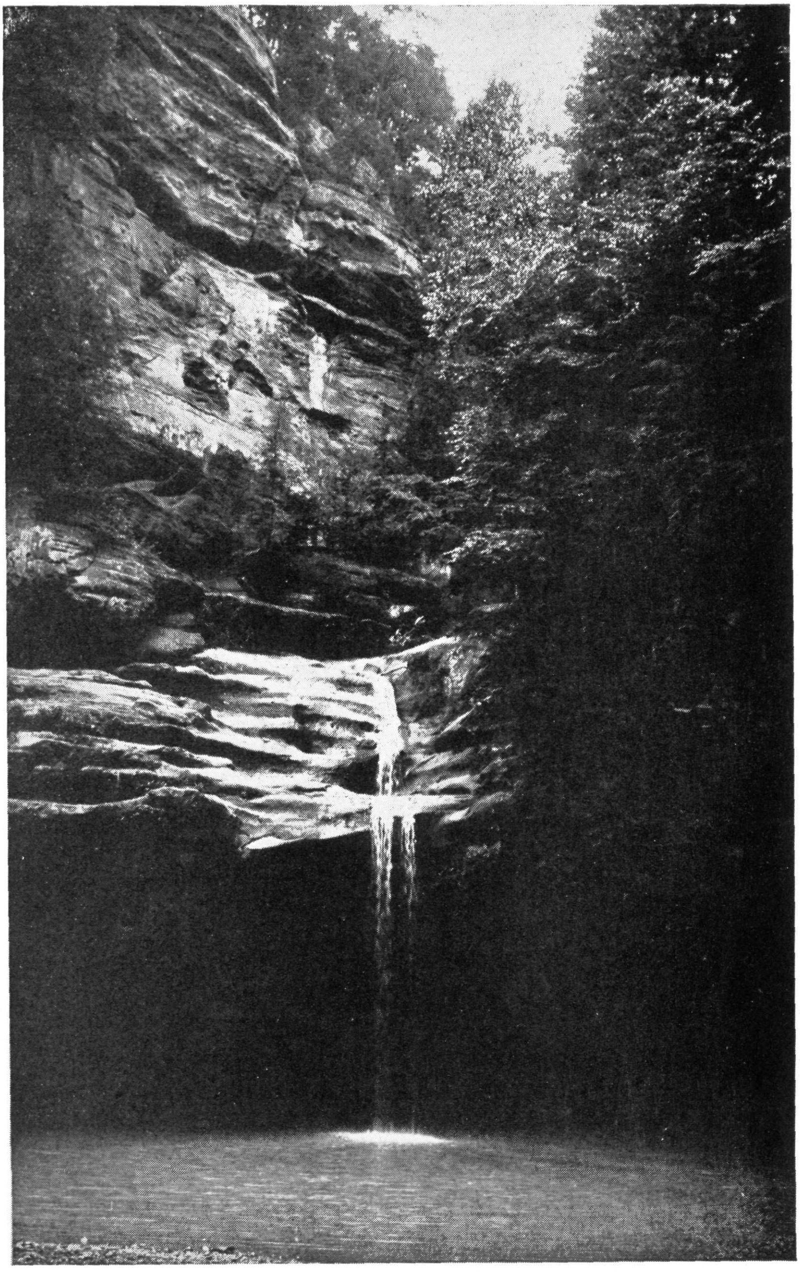


Fig. 26. The Lower Falls by which Old Man's Creek enters the head of the Lower Gorge. The falls is over only the lower part of the Black Hand sandstone but the entire formation is shown in the valley wall. The plunge basin is probably in the Cuyahoga shale below.

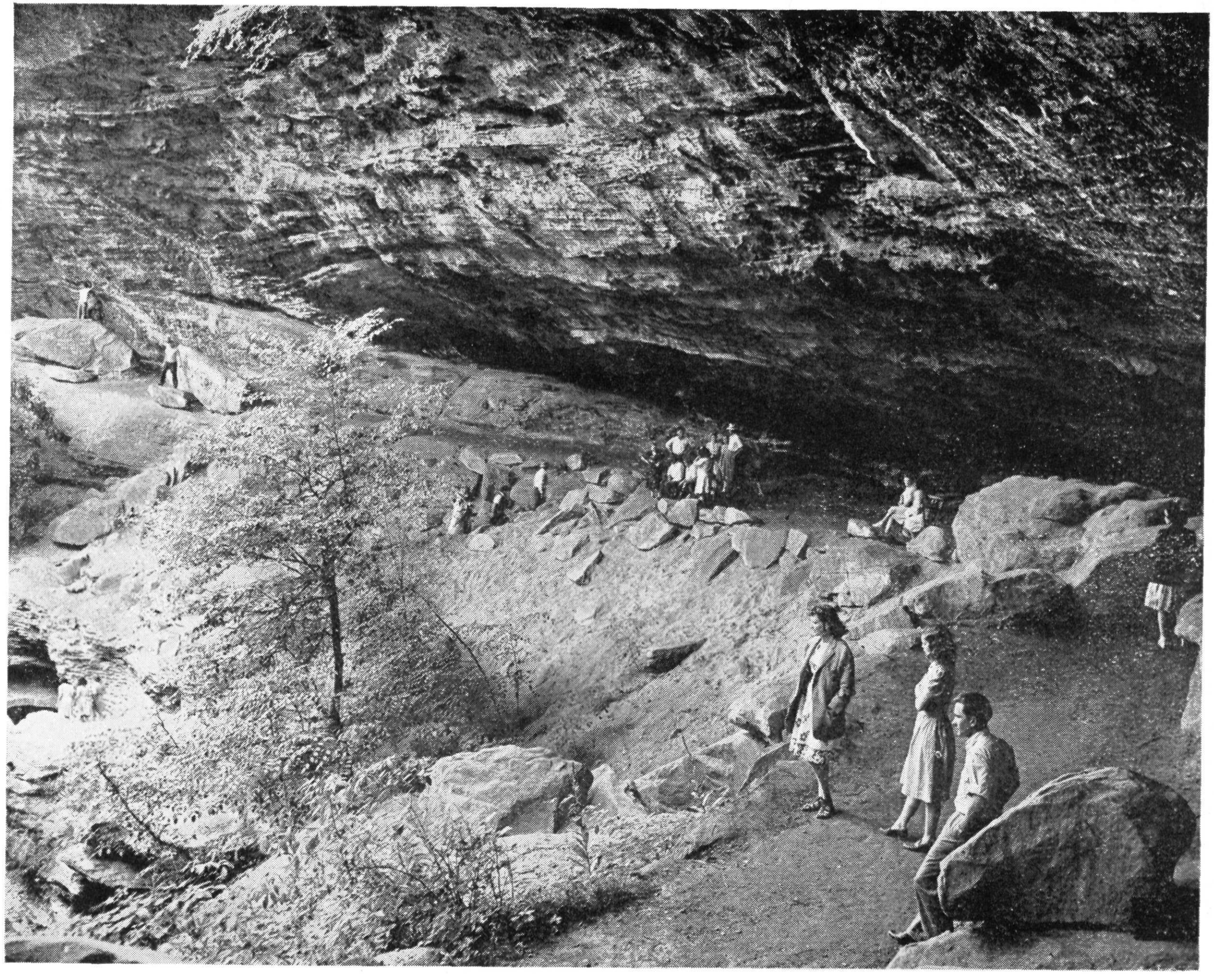


Fig. 27. Old Man's Cave looking down the valley. The sloping ceiling and the uneven weathering of the sandstone are well shown. (Ohio Division of Forestry. Photo by Bob Wheaton).

Fig. 28. The Black Hand sandstone cliff on the face of Rock House. The dark reentrants are the windows leading into Rock House. (Ohio Division of Forestry. Photo by Bob Wheaton).

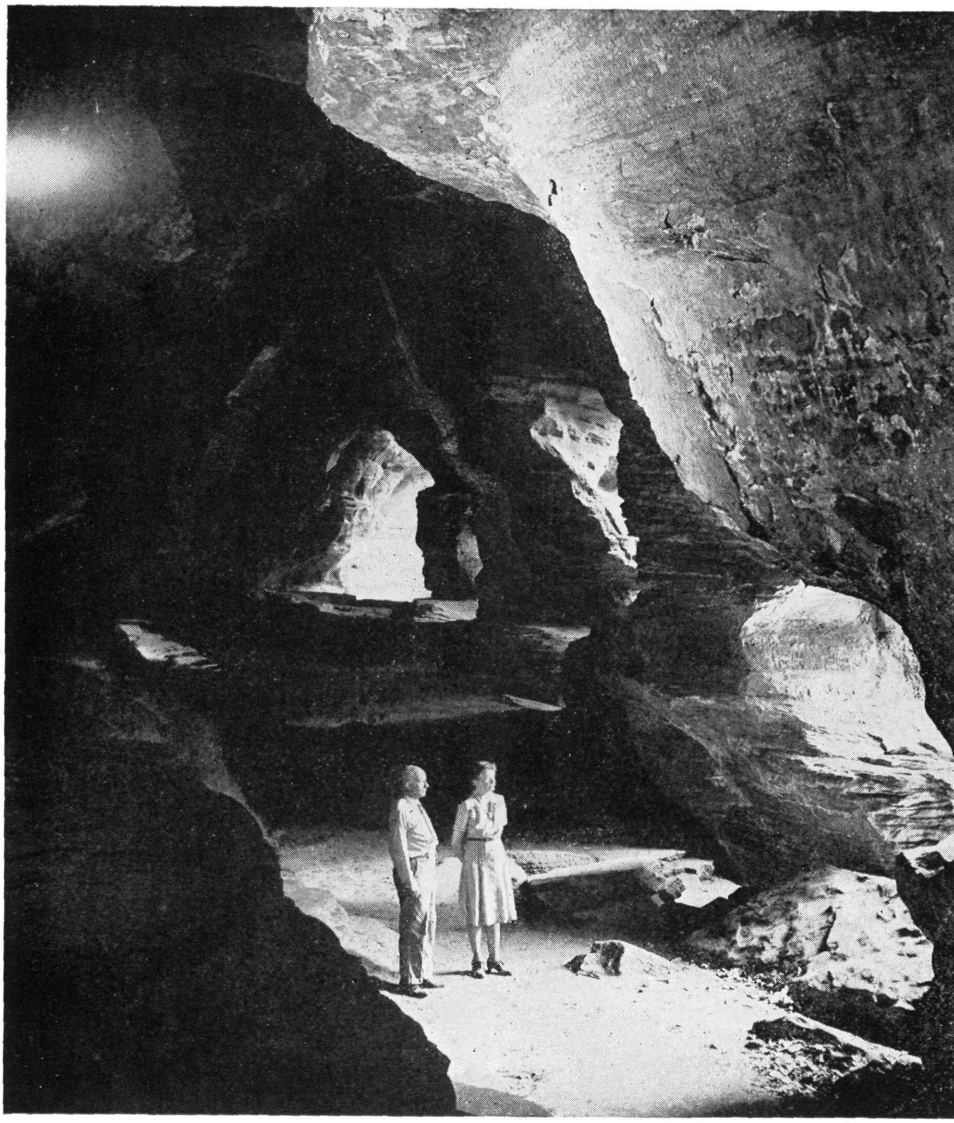


Fig. 29. Looking southwest along the corridor of Rock House showing the open southwest end and the windows on the right which admit the light. (Ohio Division of Forestry. Photo by Bob Wheaton.)

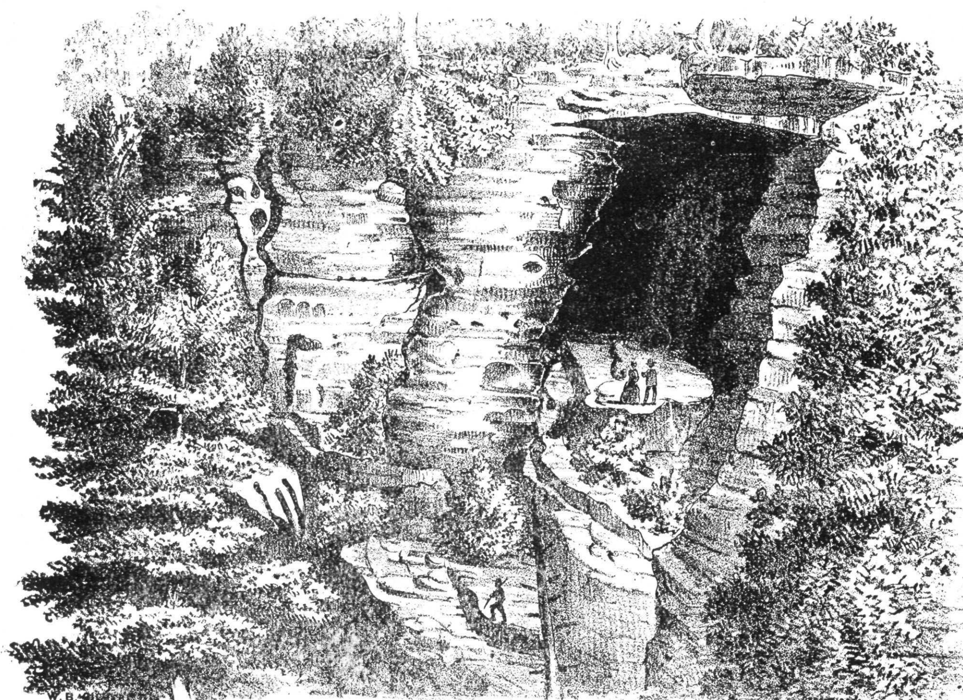


Fig. 30. The opening at the southwest end of Rock House protected by a rock canopy of the firm upper beds of the Black Hand sandstone. (Geol. Surv. Ohio, Report of Progress in 1870.)

A second set of joints, somewhat unequally spaced, cuts the sandstone approximately at right angles to the cliff and to the master joint along which Rock House is developed (see Fig. 31). Weathering along these joints has made window-like openings through the outer wall of Rock House. Five such openings exist and cut the outer wall into six great pillars of quite unequal size. The line of the

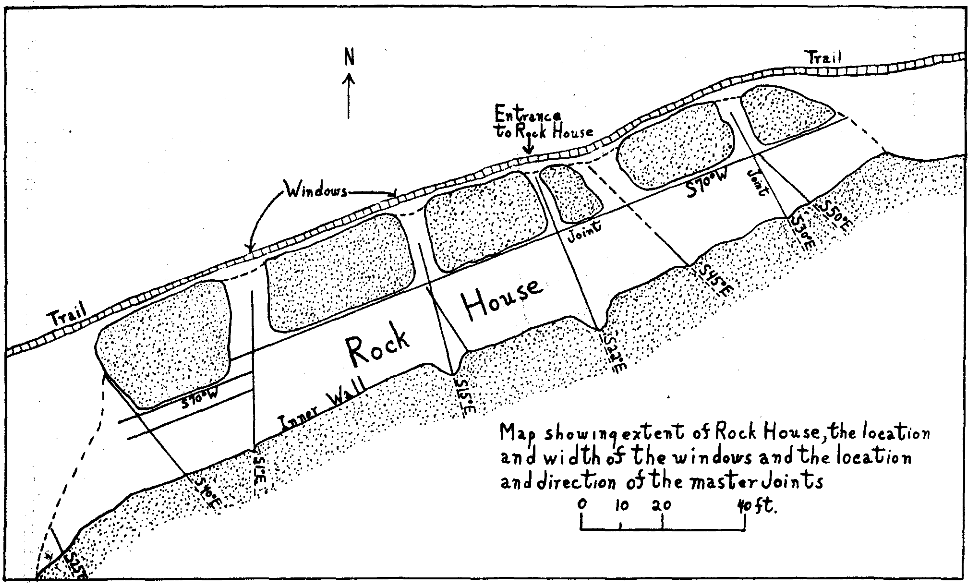


Fig. 31. Map showing the extent of Rock House, the location and width of the windows, and the location and direction of the master joints.

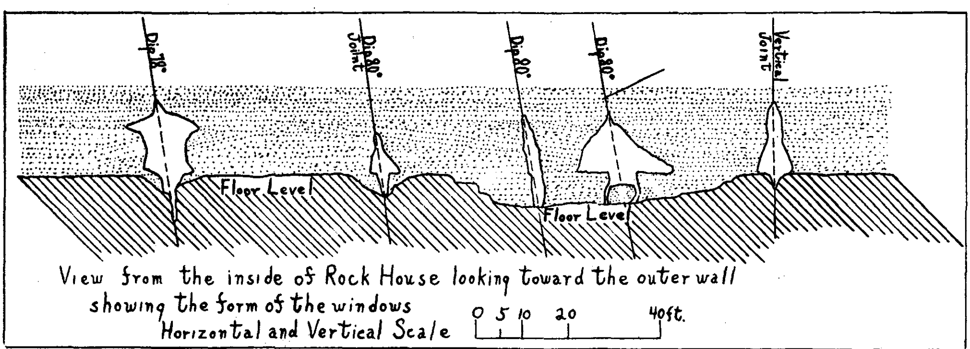


Fig. 32. View from the inside of Rock House looking toward the outer wall showing the form of the windows, and the position of the cross joints.

joint fracture that caused each opening can be traced across the roof of Rock House and down the inner wall where a weathered out niche marks the line of each joint. The window-like openings, as shown in Figure 32 also have the form of Gothic arches and the great pillars are smallest at the base and enlarge upward to compensate for the form of the window openings.

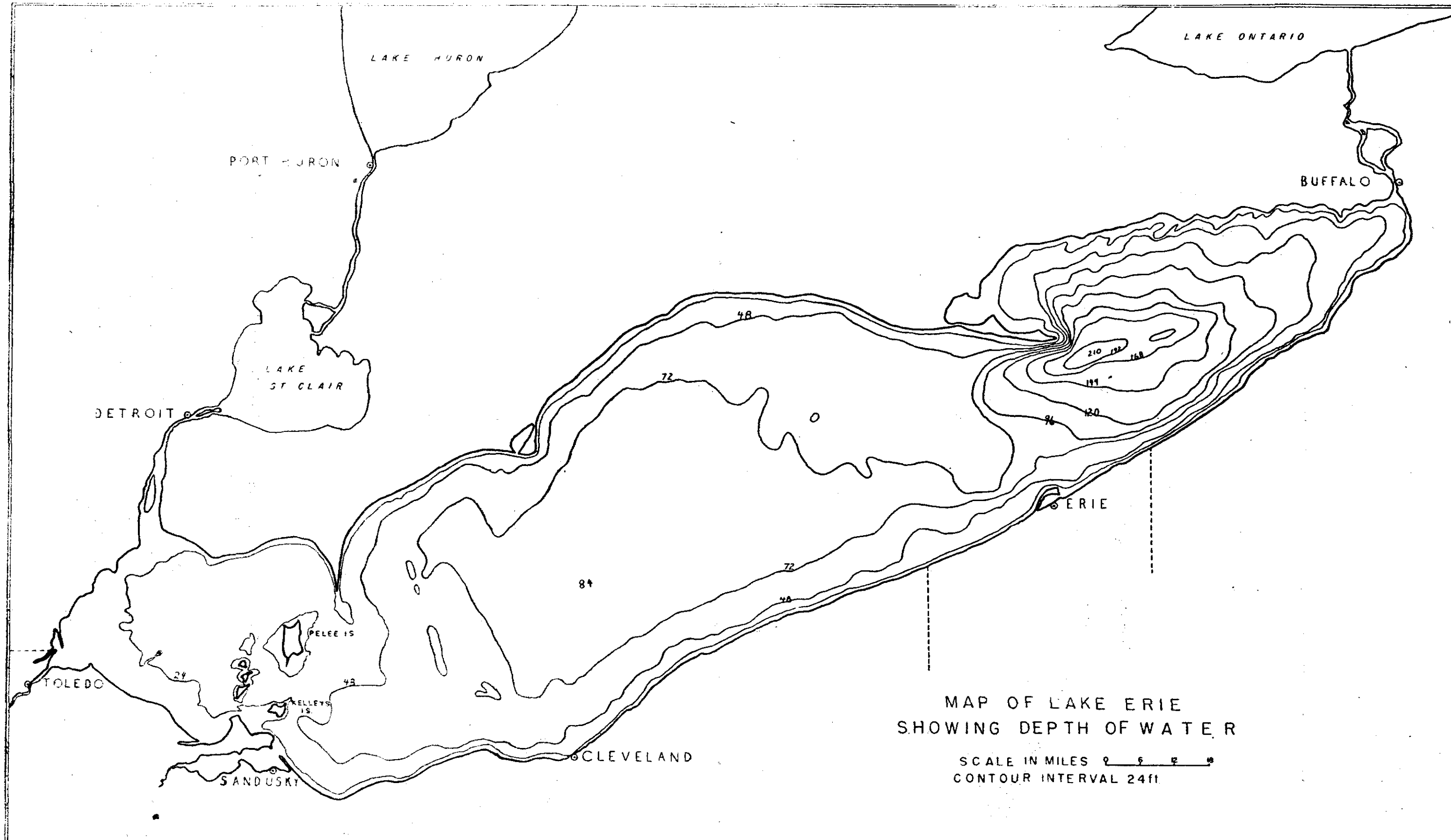


Fig. 33. Map of Lake Erie showing by contours the depth of the water, which furnishes a basis for a division into eastern, central, and western units.

The middle one of the five openings is the easy entrance to Rock House but two other openings and the northeast end can be entered by climbing. The southwest end of Rock House opens out at 30 to 40 feet above the base of the cliff as so well shown in Figure 30 reproduced here from an old sketch first published in a report of the Geological Survey of Ohio in 1870. Above this opening thick beds of the firmer upper part of the Black Hand sandstone project like a canopy above and beyond the opening. Rock House, like the several rock-shelter caves, is developed in the horizon of the cross-bedded, poorly-cemented middle part of the Black Hand sandstone.

The evidence is conclusive that the greater weathering of the sandstone along the joints has been the chief cause for the formation of Rock House. The sandstone is rather loosely cemented and the slow but persistent decay of the cement allows sand grains to fall away from ceiling and walls. It is believed this is the chief method of enlargement.

If it appears that the slow falling away of sand grains is an inadequate method for forming the great corridor of Rock House, it may be noted that if the sand necessary to fill the 100,000 cu. ft. of space in Rock House was removed during the one million years of the Pleistocene period the rate of removal would be about one-half of an ounce of sand grains per day, which does not seem an unreasonable rate. It is believed that wind is the most important and almost the sole agent for the removal of the sand grains from the floor of Rock House.

LAKE ERIE BASIN AND ISLANDS

The Lake Erie basin may be very naturally divided on the basis of depth into three parts which by location may be called the eastern, central, and western sections, as shown in Figure 33. The Eastern section east of a line from Erie, Pennsylvania, to the base of Long Point on the north shore is the deepest part with considerable area below 120 feet and a maximum depth of 210 feet. The Central section is a broad basin with a relatively even bottom and of intermediate depth largely between 60 and 75 feet, and with a maximum of 84 feet.

The Western section, west of a line from Point Pelee to Cedar Point at Sandusky is the shallowest and the smallest part with most of the floor between 25 and 35 feet and the deepest record 48 feet. In contrast with the other two sections the Western section contains a number of islands and shoals in its eastern part which partly close it off from the Central section.

A satisfactory explanation of the varying depth of the Lake Erie basin can apparently be found in the differential hardness of the bedrock and in erosion by streams and by the ice sheets. The rock strata of the Lake Erie region dip slightly to the south and the outcrop bands of the several rock units have a general east-west direction roughly paralleling Lake Erie. (Fig. 34). Lake Ontario basin, including the plain southward to the base of the Niagara escarpment is underlain by Ordovician shale. Ontario, north of Lake Erie is underlain by an east-west belt of resistant Silurian and Devonian limestone and dolomite. The basin of Lake Erie east of Sandusky is underlain by shale, shaly limestone and shaly sandstone of Upper Devonian age. Along the south border of the Lake Erie basin eastward from Cleveland there is an escarpment composed largely of Mississippian sandstone rising 200 to 300 feet above the floor of the lake basin as shown in Figure 36. This is the northwest front of the Appalachian Plateau.

The glacial ice which invaded the Lake Erie region came from the northeast over the Silurian-Devonian limestone cuesta of Ontario, and down the dip-slope into the Erie basin. Here its southward advance was obstructed by the escarpment bordering the basin on the south and the ice was directed southwestward along the line of the basin which was along the outcrop of the softer Upper Devonian shales (see Fig. 34). In the narrow eastern part of the basin these shales were eroded deeply but farther west where the angle of southward dip is less and the width of the shale belt is greater, the glacial erosion resulted in the broader but shallower central section.

Between Cleveland and Sandusky the outcrop belt of the Devonian shales swings southward across central Ohio (Fig. 34). The shallow western section of Lake Erie is underlain by the Silurian and Devonian limestones on the northward plunging end of the Cincinnati anticline and on these resistant rocks the glacial erosion was slight and the western section of Lake Erie is shallow (see Figs. 34 and 33).

In the eastern part of this western section there are a number of islands as shown in Figure 35. Five of these have areas greater than one square mile and there are a dozen more of smaller extent as well as a number of shoals. The islands are arranged in two north-south belts. The western belt starts with Catawba Island, which is really a part of the mainland, and is continued north-

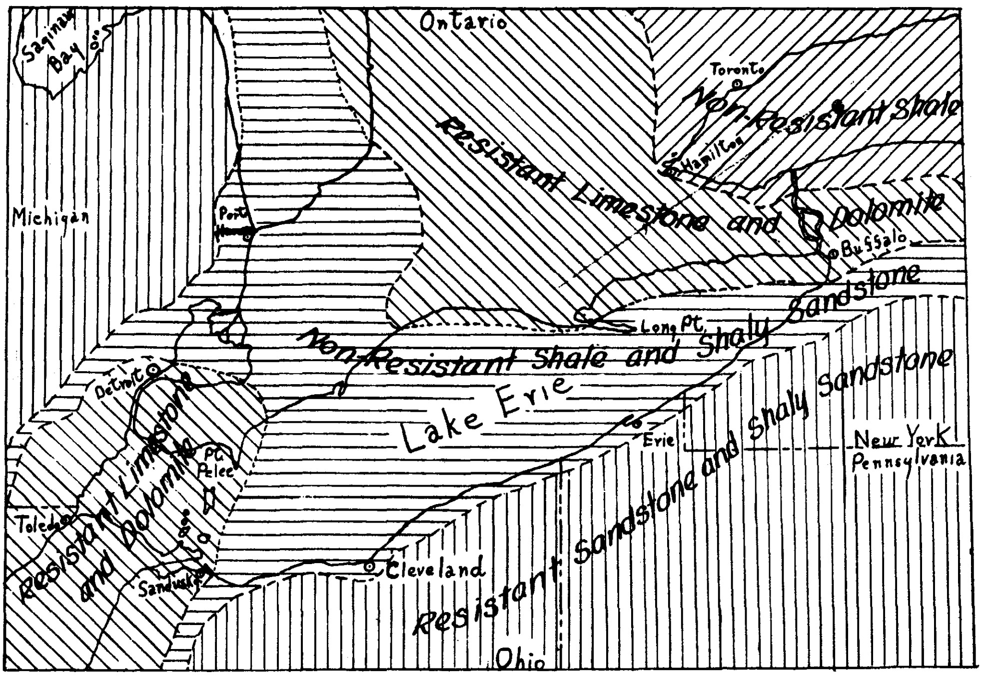


Fig. 34. Map of the Lake Erie region showing the distribution of the several rock types that have determined the relief features.

ward by the Bass Island group of three larger islands and several small nearby islands. North of the Canadian line the belt swings northwest and includes Hen Island, Big and Little Chicken Islands, East Sister, Middle Sister, and North Harbor Islands and several wave-swept reefs and shoals.

The east belt begins with the elevated east end of Marblehead peninsula and is continued northward by Kelleys Island, Middle Island just across the Canadian line, and Pelee Island the largest of the Lake Erie islands.

Some characteristics of the islands, and their relation to the lithology and structure of the bed rocks, are shown in the east-west generalized cross-section through South Bass, and Kelleys islands that forms Figure 37. This island area is on the east flank of the Cincinnati anticline and the strata dip eastward at a low angle. The rock section of the region includes the Upper Silurian Bass Island dolomites, Greenfield, Tymochtee, Put-in-Bay and Raisin River and the Devonian units, Amherstburg and Lucas dolomites and Columbus and Delaware limestones. Both island belts are north-south cuesta ridges with steeper slopes on the west and gentler slopes to the east. The western or Bass Island ridge is formed chiefly by the very resistant Put-in-Bay dolomite. The eastern or Kelleys Island ridge is formed by the Columbus limestone.

Along the south part of the west shore of South Bass Island and the northwest shore of Catawba Islands there are bold rocky cliffs 30 to 40 feet high formed of the massive brecciated Put-in-Bay dolomite as shown in Figure 38. Such rugged

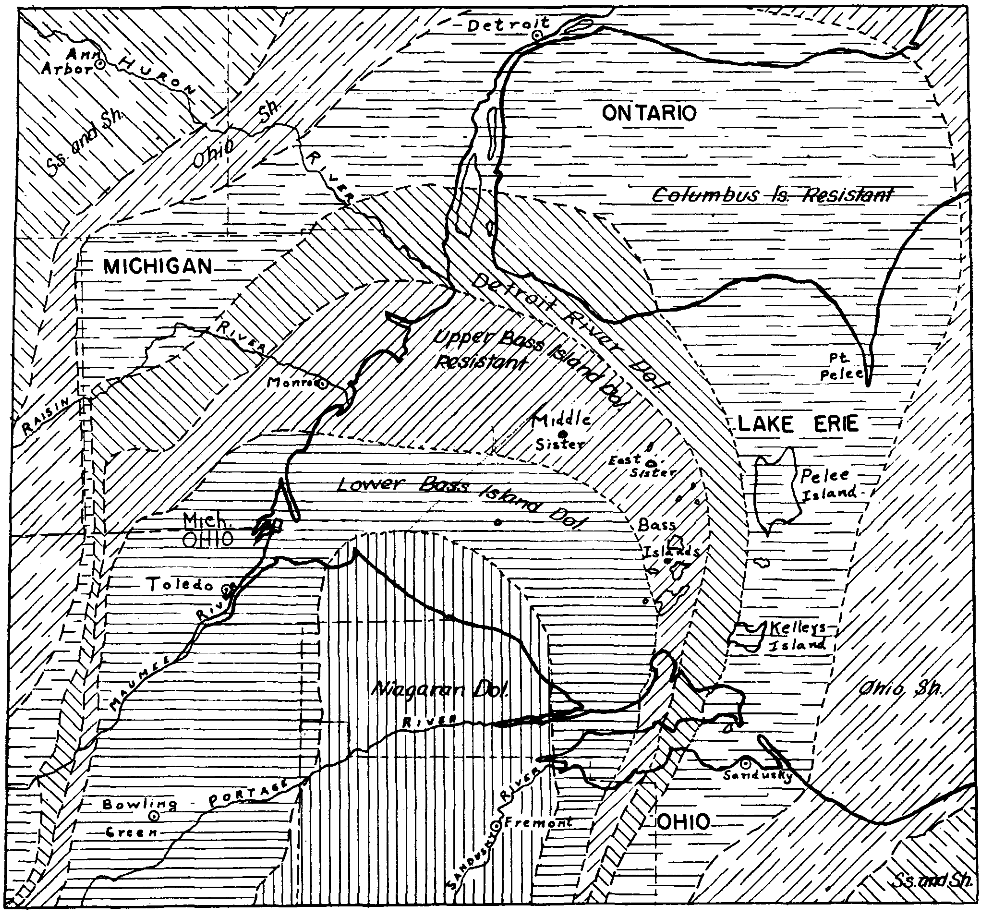


Fig. 35. Geologic map of the region around the west end of Lake Erie showing the relation of the island belts to the lithology and relative resistance of the rock units.

features are unusual for western Lake Erie or western Ohio. The lake level here is in the upper part of the next lower unit, the Tymochtee member, a soft, shaly, thin-bedded dolomite. This is eroded readily by the waves and the massive stone above is undermined and falls away in great blocks. The bed of the lake for some miles to the west is underlain by the Tymochtee shaly dolomite (see Fig. 37). Both South Bass and Catawba islands have their greatest elevations near the west shore and a general slope toward the east. This is the dip-slope of the cuesta on the bedrock surface which at places passes gradually beneath the lake surface.

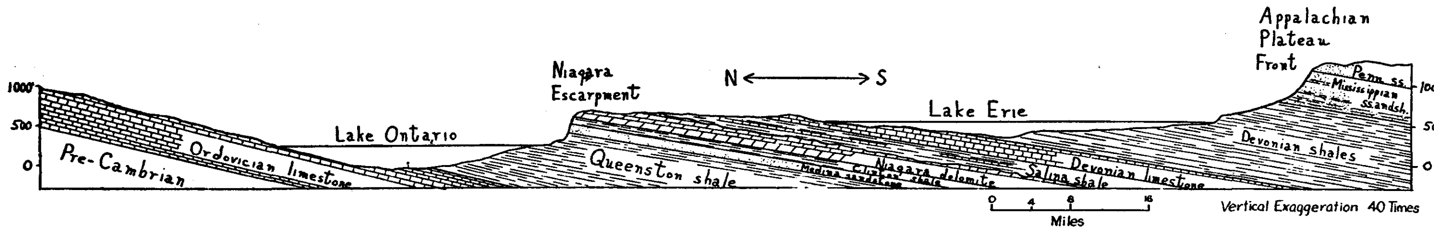


Fig. 36. North-south section across the Ontario and Erie basins and the adjoining uplands showing the relations of the basins and uplands to the lithology of the rock units.

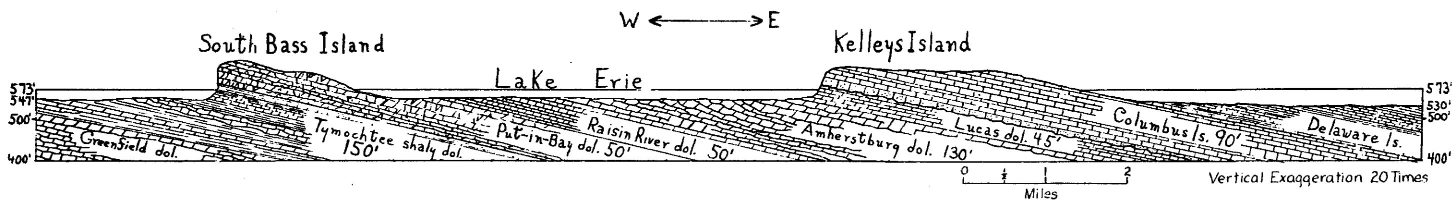


Fig. 37. East-west section through South Bass and Kelleys islands showing the cuesta form of the islands, the rock units, and the rock structure.

Although less high and less rugged, Kelleys Island on the eastern ridge also shows the cuesta form (Fig. 37). The highest elevation of the island is in the western part, and around the west shore there is generally a cliff 10 to 20 feet high the upper part of which is Columbus limestone while the lower part, at water level, is the somewhat thinner-bedded Lucas dolomite. On the east side of the island the surface slopes evenly and gently eastward toward the lake and along the shore there are large bedrock, dip-slope areas, in part glacially smoothed and striated, which pass without interruption or change beneath the lake surface.

On the floor of the channel between the two ridges the Raisin River, Amherstburg and Lucas dolomites must outcrop (see Fig. 37). As exposed on Marblehead peninsula on the south shore of Lake Erie and also along Detroit River to the north these units have a combined thickness of 150 to 200 feet. They are less resistant than the Put-in-Bay and the Columbus, and therefore form the low channel between the ridges.

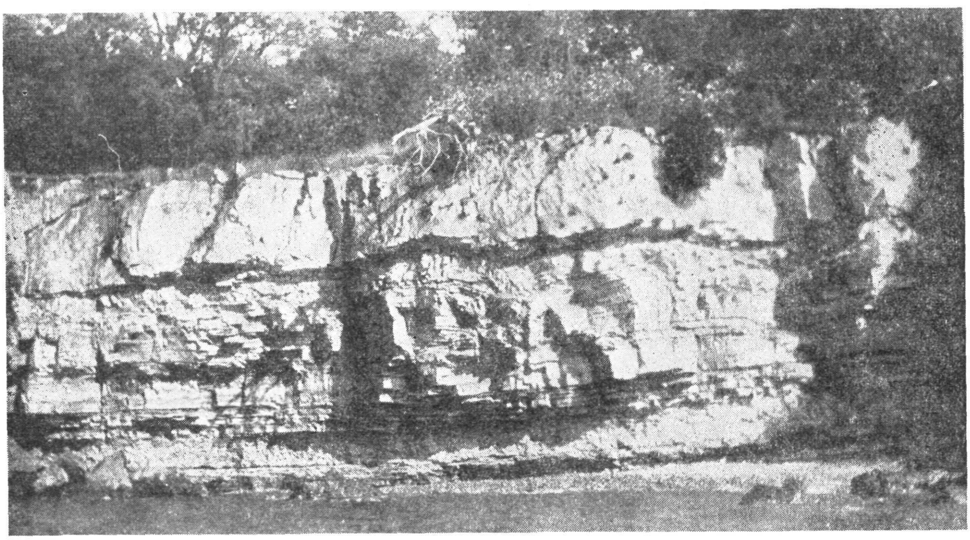


Fig. 38. Cliff along the south part of the west shore of South Bass Island. The massive brecciated Put-in-Bay dolomite which forms the cliff is being undercut near lake bed in the Tymochtee shaly dolomite.

The swing of the Cuesta ridge to the northwest is due to the swing of the outcrop belt around the end of the northward plunging Cincinnati anticline (see Fig. 35). The Put-in-Bay-Raisin River outcrop belt swings west to appear on the Michigan shore in the vicinity of Monroe and thence runs southwest across southern Monroe County and south across western Lucas County on the west side of the anticline. The Columbus limestone belt of outcrop which runs north from Pelee Island to the Ontario peninsula likewise swings westward around the end of the anticline into Michigan near Detroit and thence southwest and south on the west side of the anticline.

In conclusion may I express the hope that this little excursion into the field of geology, in which we have tried to point out the genetic relations of relief features to rock materials and the work of the common geologic agents, may in some measure increase your appreciation of scenic features, and also leave with you the realization that most of the surface features which surround us are the result of the work of common geologic agents working slowly but relentlessly through long intervals of geologic time.